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Investigation of Emerging Technology for Hydrocarbon and Particulate Emissions from Stationary Sources

Acurex Corp, Mountain View, CA Energy and Environmental Div

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INVESTIGATION OF EMERGING TECHNOLOGY FOR HYDROCARBON AND PARTICULATE EMISSIONS FROM STATIONARY SOURCES

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16. Abstracts The objective of this project is to identify emerging control technologies that are or may become commercially available by 1985 for stationary hydrocarbon and particulate emissions sources. The report details a matrix of applicable control techniques, percent emission reductions achievable, schedules of availability, and costs. Emphasis is on identifying control techniques more stringent than the LAER techniques previously defined for EPA's policy study of nonattainment areas. This study finds that: (1) for most ducted emissions from particulate sources fabric filters and electrostatic precipitators will remain the most advanced control technology; (2) there are a range of hydrocarbon control techniques that offer the potential for reducing emissions through 1985 and beyond - the more important of these being the activated carbon and wet scrubbing control technologies. Contains tables, diagrams, and references.

17. Key Words and Document Analysis. 17a. Descriptors
Emerging Techniques for Air Pollution Control from Stationary Sources
Hydrocarbon Air Pollution Control
Particulate Air Pollution Control
Air Pollution control cost estimates
Air pollution control efficiency estimates
Emissions-offset policy
Ambient Air Quality standards
Nonattainment of ambient Air Quality Standards
New Source Pollution Control Standards
Lowest Achievable Emission Rate

17b. Identifiers/Open-Ended Terms
fabric filters
electrostatic precipitators
high pressure, high temperature filtration technology
activated carbon and wet scrubbing control technologies
ducted emissions
fugitive emissions
H.G.M.S. (High Gradient Magnetic Separator Control Technology)

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SECTION 1

INTRODUCTION

Background

EPA's Office of Planning and Evaluation is conducting a study to assess the emissions offset policy and to identify control requirements necessary to attain and maintain the ambient air quality standards. To support this effort, definitions of the Lowest Achievable Emission Rate (LAER), consistant with the 1977 Clean Air Act Amendments, have been generated by Engineering Sciences, Inc. for stationary hydrocarbon and particulate sources. However, there is a need to assess the limiting case of near-maximum control technologies beyond LAER that may be available by 1985. These technologies would be identified using more flexible criteria than specified by the 1977 Clean Air Act Amendments.

EPA's offset policy is being evaluated in the context of an overall study of the problems of AQCR's that may not achieve the ambient standard in the near future. The extent to which new growth can be accomodated in these nonattainment areas is a direct function of the availability of additional emission reductions which can be used to offset new source emissions. EPA's study of problems in these nonattainment areas indicated that installing Reasonably Available Control Technology (RACT) at existing sources and LAER (as defined for purposes of this study) at new sources may not ensure attainment of the standards by the statutory deadlines.

Preliminary analyses by Engineering Sciences, Inc. of the demand for and supply of offsets in the Houston AQCR over the next decade have indicated that demand far outstrips supply. Estimates of LAER used by ESI (estimated without regard to cost of the technology), coupled with reductions from existing sources to SIP or RACT levels, did not appear to produce sufficient supplies of offsets to satisfy the demand of anticipated new sources.

Because of this uncertainty, the Office of Planning and Evaluation desired to investigate whether control technologies affording emission reductions beyond the LAER estimates used in the ESI study may be available and whether such reductions could be shown to ensure timely attainment of the standards. Whether or not such controls beyond LAER would actually be used or required depends upon the cost of such controls and the prevailing price of offsets.

Objective

The objective of this project is to identify emerging control technologies for stationary hydrocarbon and particulate sources. Identification of these controls was accomplished through contacts with vendors, other R&D groups and review of available literature and was not restricted by consideration of their costs. This final report details a matrix of applicable control techniques, percent reductions achievable, schedule of availability, and costs. The emphasis was on defining control techniques more stringent than the LAER techniques previously defined for EPA's study of nonattainment areas.

Much of the information in this report was derived from literature or vendor contacts and not further verified by us. Other information was estimated specifically for the offset study and based on generally

accepted engineering principles. Consequently, we caution that these data and information in this report be used only for modeling or other approximate purposes.

Conclusion

Having reviewed available literature (journals, periodicals, proceedings, etc.) and having contracted control vendors, we believe that there are very limited new domestic control technologies with emission reduction beyond LAER. Although our search focused on domestic literature, our review of abstracts of foreign literature and reports on foreign R&D leads us to a similar conclusion regarding foreign technology. In this review, we have identified several new or improved technologies that offer emission reductions greater than the LAER techniques used by EPA earlier; these techniques are presented in Sections 2 and 3 of this report. Capital and operating costs and efficiencies are included for most of these technologies.

SECTION 2

EMERGING TECHNOLOGIES FOR PARTICULATES STATIONARY SOURCES

This section presents data on emerging control technologies that are or may become commercially available for particulate sources by 1985. The emphasis is on identifying controls that afford more emission reduction than available through the estimates of the LAER reductions used earlier by the Agency in its evaluation of the offset policy. Cost of control was not a criterion for selecting those technologies to be included here.

The Office of Planning and Evaluation prepared lists of major stationary particulate sources for 3 AQCR's (Houston, Chicago, and Philadelphia) for which there is presently concern over attainment of the ambient air quality particulate standards. Table 2-1 presents these lists of sources and processes. Tables 2-2, 2-3 and 2-4 present the emerging control technologies that we identified for the listed sources in each of these AQCR's. For each listed source, the following is presented where available:

- Abatement technology
- Range of control
- Application limitations
- Cost
- Commercial availability

TABLE 2-1. MAJOR PARTICULATE SOURCES IN THE HOUSTON, PHILADELPHIA AND CHICAGO AQCR'S (COMPILED FOR THIS STUDY BY THE OFFICE OF PLANNING AND EVALUATION)

HOUSTON	PHILADELPHIA	CHICAGO
Stone quarry and rock processing	Paved road	Oil and coal-fired power plants
	Unpaved roads	
	Mud and dirt	
Concrete block and brick manufacturing	Carryout from construction sites	Secondary aluminum, copper and lead smelting
Industrial oil and gas-fired boilers	Coal-fired powerplants	
	Oil-fired industrial boilers	Grey iron foundaries
Feed grain elevators		Steel foundaries
	Steel foundary	Lime calcining
Gas-fired utility boilers	Chemical manufacturing (Sulfide kiln)	Refineries
Phosphate fertilizer		Feed grain elevators
	Petroleum refinery fluid coker gas process heaters	Stone quarries
Iron and steel • General sintering • Ore charging furnaces • Electric arc lancing		Carbon black
	Asphalt dryer	Asphaltic concrete
	Cement storage	
		Incinerations
Cement manufacturing	Fiberglass manufacturing	
Petroleum refineries • Process heaters • Fluid catalytic crackers	Sand drying	

TABLE 2-2. TSP CONTROL TECHNIQUES FOR STATIONARY SOURCES (HOUSTON)[a]

Process	Abatement Technology	Range of[5] Control	Applications Limitations	Cost[4]/acfm	Commercial Availability	Comments
Stone quarry and rock processing 305 020 01-99[b]	Fabric filters, ESP's	90+%	The typical quarry and rock processing facility has numerous sources of particulate emissions -- from haul roads to conveyor discharges, to truck loading. Collection of the particulate emissions and ducting to a control device is the primary limit on controlling these emissions	$3.50-6.50 plus cost of ducts and hoods installed $1-2 per year operating cost	Now	The use of hoods, and ducting emissions to a control device is available technology but costs have been prohibitive due to the large number of and distribution of sources. Small filter units can be used at transfer and dump points to collect a major share of fugitives.
Concrete block and brick manufacturing	Fabric filters, and ESP's	90+%	Large number of and distribution of particulate sources generates the need for hoods and ducting -- see limitations under quarry and rock processing.	$3.50-6.50 plus cost of ducts and hoods installed $1-2 per year operating cost	Now	See comments under quarry and rock processing. The collection devices themselves are capable of 99.9+% efficiencies. Large fugitive emissions are included to get 90% shown.
Industrial oil and gas fired boilers 102 004 01,02	Fabric filters, and ESP's	99.99%[1]	The presence of sticky particles may limit the application of these control devices. There are, however, fabric filters currently operating on oil fired boilers with efficiencies well within current regulations	$3.50-6.50 installed $1-2 per year operating cost	Technology available now. See Comment	In order to accelerate the application of available technology to these sources, a demonstration program should be planned and executed.
Feed grain elevators 302 005 01-04 302 006 01-04	Fabric filters, and ESP's	99.99%[1]	Collection of particulate and ducting to a control device is the major requirement for achieving the high collection efficiencies which are indicated.	$3.50-6.50 plus cost of ducts and hoods installed $1-2 per year operating cost	Now	

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[a]Footnotes are listed on pages 2-16 through 2-20
[b]Source Classification Code

TABLE 2-2. Continued [a]

Process	Abatement Technology	Range of Control [5]	Applications Limitations	Cost [4]/acfm	Commercial Availability	Comments
Gas fired utility boilers	Fabric filters	Up to 99.99% [1] depending on particulate parameters	Particulate can be expected to be essentially all fine particles -- may be difficult to clean from filter elements	$3.50 to $6.50 installed $1-2 per year operating cost	Technology available now. See comment.	When applying current technology to existing but previously uncontrolled sources, a need exists for demonstration testing on a representative source. A small scale demonstration program, applying fabric filters to a gas fired boiler should be conducted.
Phosphate fertilizer	Fabric filters, ESP's	Up to 99.99% [1] depending on particulate parameters		$3.50 to $6.50 installed $1-2 per year operating cost	Technology available now. See comment.	ESP's have successfully been applied to phosphate rock processing. Fabric filters may, however, prove to offer a greater degree of control. A small scale demonstration should be planned and executed to demonstrate the viability of this technology.
Iron and steel • general sintering • ore charging of blast furnaces • electric arc lancing	Fabric filters, ESP's, HGMS, high temperature filtration	Up to 99.99% [1,2]	The difficulty of controlling iron and steel emissions is typically one of collecting the particulate and ducting them to a control device. Due to extreme temperatures of some emissions, large quantities of dilution air, or judicious use of water sprays have been used to control temperatures.	$3.50 to $6.50 installed $1-2 per year operating cost	All but HGMS and high temperature filtration are commercially available now. High temperature filtration available 1982. Availability of HGMS dependent on results of ongoing research.	
Cement manufacturing	Fabric filters, ESP's, high temperature filtration	Up to 99.99% [1,2]	Presence of water vapor in effluent requires careful design and operating procedures to avoid bag blinding or sticking of particulate to collection surfaces.	$3.50 to 6.50 installed $1-2 per year operating cost	Now except for high temperature filtration available 1982.	See comments of iron and steel.

[a]Footnotes are listed on pages 2-16 through 2-20

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TABLE 2-2. Concluded[a]

Process	Abatement Technology	Range of[5] Control	Applications Limitations	Cost[4]/acfm	Commercial Availability	Comments
Petroleum refineries • process heaters • fluid catalytic crackers	Fabric filters, ESP's	Up to 99.99%[1]	Effluent collection and ducting to a control device is the most difficult aspect of applying these technologies.	$3.50 to 6.50 installed $1-2 per year operating cost	Now	The use of hoods, and ducting emissions to a control device is available technology but costs have been prohibitive due to the large number of and distribution of sources. Small filter units can be used at transfer and dump points to collect a major share of fugitives.

[a]Footnotes are listed on pages 2-16 through 2-20

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TABLE 2-3. TSP CONTROL TECHNIQUES FOR STATIONARY SOURCES (PHILADELPHIA)[a]

Process	Abatement Technology	Range of[5] Control	Applications Limitations	Cost[4]/acfm	Commercial Availability	Comments
Paved roads Unpaved roads Mud and dirt Carryout from Construction Sites	1. Improved Street Cleaning • Broom Sweeping • Vacuum Sweeping • Regenerative Air Cleaning • Flushing 2. Modified Snow and Ice Procedures • Replace Sand with Salt or a Salt/Sand Mixture • Plow instead of salt or sanding • Remove anti-skid material as soon as possible • Apply less material 3. Control of Dirt and Mud Carryout from Major Sources (construction site) through application of water and sweeping 4. Road paving/ surface treatments Paving unpaved roads, oiling or surface treating other surfaces	Effectiveness is a function of ambient loadings, device employed, source of particulate The range of controls is dependent upon methodology selected, ambient monitoring employed and local meterological conditions.		See Comments	See Comments	A "Comprehensive" review on the subject of reentrained dust from paved streets was concluded in August 1977 by PEDCo Environmental. The following comments are summarized from their final report (3). • Reentrained portion of dust is an order of magnitude greater than direct emissions from vehicle exhaust (0.34g/veh/mi) or tire wear (0.20g/veh-mi) • Particulate emissions were found to be directly proportional to traffic volume • Suspended particulate samples taken near streets has a mass median diameter of 15 m • Mineral matter constitutes 59% by weight (tire tread and biological material constitute 1%+, inorganic lead 1-2%) • Conclusions from PEDCo's study: 1) There was no consistent relationship between street surface loadings and nearby particulate concentrations 2) Since the rate of reentrainment was shown to be uncorrelated to the amount of material on a street, reducing the amount of material by street cleaning "might not consistently reduce particulate con-concentrations." 3) Mud carryout control from construction sites showed significant reductions in particulate concentrations 4) Traffic reductions may be effective in reducing particulate concentrations 5) The costs (1977) for particulate

[a]Footnotes are listed on pages 2-16 through 2-20

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TABLE 2-3. Continued [a]

Process	Abatement Technology	Range of Control[5]	Applications Limitations	Cost[4]/acfm	Commercial Availability	Comments
	5. Control of Dirt and Mud Carryout from ubiquous sources, (unpaved parking areas, unpaved shoulders and driveways) by sweeping, application of water on paving 6. Reduction in traffic volumes on a street					reductions were estimated to be on the order of $1000 per $\mu g/m^3$ in annual average concentrations over an area of 1 mile radius 6) In most cases studied, it was concluded that mud carryout controls or improved street cleaning (in areas where it can be demonstrated to be effective) would be more cost-effective in reducing urban particulate concentrations than additional point source or area source controls
Coal Fired Powerplants Oil Fired Industrial Boilers 101 002 -01, 02, 99 102 004 -01,[b] 02	Fabric Filters	Up to 99.99% depending on particulate	Presence of water vapor may lead to bag blinding	$3.50 to 6.50 installed $1-2 per year operating cost	Technology available now. See Comment.	When applying current technology to existing but previously uncontrolled sources, a need exists for demonstration testing on a representative source.
Steel Foundary 304 007 99	Fabric filters, ESP's, HGMS, high temperature filtration.	Up to 99.99%[1,2]	The difficulty of controlling iron and steel emisssions is typically one of collecting the particulate and ducting them to a control device. Due to extreme temperatures of some emissions, large quantities of dilution air and water sprays have been used to control temperatures	$3.50 to $6.50 installed $1-2 per year operating cost	All but HGMS and high temperature filtration is commercially available now. High temperature filtration available 1982. Availability of HGMS dependent on results of ongoing research.	High temperature (1500°F) filtration could offer significant economic advantages through recovery of heat energy currently being wasted.

[a]Footnotes are listed on pages 2-16 through 2-20
[b]Source Classification Codes

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TABLE 2-3. Concluded [a]

Process	Abatement Technology	Range of[5] Control	Applications Limitations	Cost[4]/acfm	Commercial Availability	Comments
Chemical Manufacturing (Sulfide kiln) 301 -999 -99	Fabric filters, ESPs	99.99%		$3.50 to $6.50	Now	
Petroleum Refinery fluid coker gas process heaters 306 -999 -99 306 -001 -02, 04	Fabric filters	Up to 99.99%	Effluent collection and ducting to a control device is the most difficult aspect of applying these technologies.	$3.50 to $6.50 installed $1-2 per year operating cost	Now	The use of hoods, and ducting emissions to a control device is available technology but costs have been prohibitive due to the large number of and distribution of sources. Small filter units can be used at transfer and dump points to collect a major share of fugitives.
Asphalt Dryer 305 002 01	Fabric filter, ESP	99.99%		$3.50 to $6.50 $1-2 per year	Now	
Cement Storage 305 006 99	Fabric filter, ESP	99.99%		$3.50 to $6.50 $1-2 per year	Now	
Fiberglass Manufacturing 305 012 04	Fabric filter, ESP	99.99%		$3.50 to $6.50 $1-2 per year	Now	
Sand drying 305 025 99	Fabric filter, ESP	99.99%		$3.50 to $6.50 $1-2 per year	Now	

[4]Footnotes are listed on pages 2-16 through 2-20

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TABLE 2-4. TSP CONTROL TECHNIQUES FOR STATIONARY SOURCES (CHICAGO)[a]

Process	Abatement Technology	Range of[5] Control	Applications Limitations	Cost[4]/acfm	Commercial Availability	Comments
Oil and Coal Fired Powerplants 101 002[b] 01-07	Fabric Filters, ESPs	Up to 99.99%[1] depending on particulate parameters	Presence of water vapor may lead to bag blinding	$3.50 to $6.50 installed $1-2 per year operating cost	Now	When applying current technology to existing but previously uncontrolled sources, a need exists for demonstration testing on a representative source.
Secondary Aluminum, Copper and lead smelting 304 001 01-99 304 004 01-99 304 002 01-99	Fabric Filters, ESPs	Up to 99.99%[1] depending on particulate parameters	High temperatures, corrosive gases and small particle sizes create a need for careful equipment design	$3.50 to $6.50 installed $1-2 per year operating cost	Now	
Grey Iron Foundaries Steel Foundaries 304 003 01, 40, 99 304 007 01-10 304 003 30-40	Fabric Filters, ESPs, HGMS, high temperature filtration	Up to 99.99%[1,2]	The difficulty of controlling iron and steel emissions is typically one of collecting the particulate and ducting them to a control device. Due to extreme temperatures of some emissions, large quantities of dilution air and water sprays have been used to control temperatures	$3.50 to $6.50 plus ducting and hoods installed $1-2 per year operating cost	All but HGMS and high temperature filtration is commercially available now High temperature filtration available 1982. Availability of HGMS dependent on results of ongoing research.	High temperature (1500°F) filtration could offer significant economic advantages through recovery of heat energy currently being wasted.
Lime Calcining 305 016 04-99	Fabric Filters, ESPs	Up to 99.99%	Effluent collection and ducting to a control device is the most difficult aspect of applying these technologies	$3.50 to $6.50 installed $1-2 per year operating cost	Now	
Refineries 306 001 04-99	Fabric Filters	Up to 99.99%	Effluent collection and ducting to a control device is the most difficult aspect of applying these technologies	$3.50 to $6.50 installed $1-2 per year operating cost	Now	The use of hoods, and ducting emissions to a control device is available technology but costs have been prohibitive due to the large number of and distribution of sources. Small filter units can be used at transfer and dump points to collect a major share of fugitives.

[a]Footnotes are listed on pages 2-16 through 2-20
[b]Source Classification Code

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TABLE 2-4. Concluded[a]

Process	Abatement Technology	Range of[5] Control	Applications Limitations	Cost[4]/acfm	Commercial Availability	Comments
Feed Grain Elevators 302 005 01-04 302 006 01-04	Fabric Filters and ESPs	Up to 99.99%[1]	Collection of particulate and ducting to a control device is the major requirement for achieving the high collection efficiencies which are indicated.	$3.50 to $6.50 plus cost of ducts and hoods	Now	
Stone Quarries 305 020 01-99	Fabric Filters, ESPs	High 90%	The typical quarry and rock processing facility has numerous sources of particulate emissions -- from haul roads to conveyor discharges, to truck loading. Collection of the particulate emissions and ducting to a control device is the primary limit on controlling these emissions.	$3.50 to $6.50 plus cost of ducts and hoods	Now	The use of hoods, and ducting emissions to control device is available technology but costs have been prohibitive due to the large number of and distribution of sources Small filter units can be used at transfer and dump points to collect a major share of fugitives.
Carbon Black 301 005 99	Fabric Filters, ESPs	Up to 99.99%[1] depending upon particulate parameters	Probability of sticky particulate may aggrevate application	$3.50 to $6.50 installed $1-2 per year operating cost	Now	Sticky particles may cause particle release problems from fabric filter surfaces and ESP collector plates.
Asphaltic Concrete 305 002 01-02 305 001, 01, 01, 99 306 011 01	Fabric Filters, ESPs	Up to 99.99%[1] depending upon particulate parameters	Potential for high temperatures requires careful design	$3.50 to $6.50 installed $1-2 per year operating cost	Now	
Incinerations 501 001 01 502 001 01	Fabric Filters, ESPs	Up to 99.99%[1] depending upon particulate parameters	High temperatures and potential for corrosive gases requires a careful engineering design	$3.50 to $6.50 installed $1-2 per year operating cost	Now	Presence of corrosive gases requires careful material selection

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There are a number of variations on these emerging control technologies that are not enumerated here but which may become available by 1985. For example, many manufacturers of scrubbers use designs that they have each evolved individually, resulting in a range of operating parameters, requirements, and efficiencies for different streams. Some, such as the Lone Star Steel Steam Hydro scrubber, are specially designed for more limited applications. The data presented in these tables have been chosen to be indicative of the control levels we believe will be achievable by 1985 through the optimum application of these and other variations. In addition, Table 2-5 presents a summary listing of each of the particulate control technologies identified. Supplementary information is given in this table on potential application to sources or processes in addition to those listed by the Office of Planning and Evaluation.

Findings

For most ducted emissions from the listed particulate sources, fabric filters and electrostatic precipitators will remain the most advanced control technology. Depending on a number of factors, the efficiency of fabric filters (including electrostatically augmented filters) can approach 99.99 percent; consistant achievement of this efficiency will require very tight design, operation, and maintenance of the control devices and cannot be expected in all cases. The temperature limitation for fabric filters is expected to be about 550^{o}F. The efficiency for ESP's can be expected to be as high as 99.9 percent; the temperature limitation is about 800^{o}F.

Electrostatically augmented scrubbers may be used in applications similar to conventional scrubbers with the exception of use in flammable

TABLE 2-5. GENERIC TSP CONTROL TECHNIQUES FOR STATIONARY SOURCES[a]

Abatement Method	Potential Process Application	Range of $ Control	Application Limitation	Schedule	Ref	Cost -- (Initial Installed)
Fabric filters[6]	Virtually all dry particulate sources	99.99%[1]	Condensed moisture blinds bags, upper temperature limit 550°F. Fabric selection based on chemical response to gas stream and temperature.	Available now	27	$3.00 - 6.50/acfm
Electrostatic precipitators wet/dry	All non-sticky (dry only) particulate sources, wet units routinely handle sticky particles	85-99.9%	Limited by particle resistivity maximum temperature 800°F.	Available now	27	Comparable to fabric filter depending on design.
Scrubbers	All (including sticky) particulate	99+%[3] depending on design and acceptable energy input.	Inertial impaction primary collection mechanism, relatively high energy use for high efficiency collection of smaller size fractions	Available now	27	$0.50-$7.00/acfm depending on design and efficiency required.
Mechanical collectors	Virtually all particulate sources	80% for 5 μm particles	Collection efficiency drops off quickly below 5 μm particle sizes.	Available now	27	$0.72-$1.30/acfm
Electrostatically augmented scrubber	Sticky particles, moist gas stream; potentially lower energy expenditures for a given collection efficiency as compared to scrubber without augmentation.	99.9%	Same as apply to conventional scrubbers except cannot be used in flammable gas stream due to potential for arcing.	Available now	1	Marginally above conventional ESP, but the technology is still under development.
Electrostatically augmented fabric filter	Same as conventional fabric filters. Potentially filter cake changes and electrically induced accelerations of particles will result in better efficiencies or the same efficiencies at lower system pressure drop.	99.99%[1]	Same as apply to conventional fabric filters except cannot be used in flammable gas streams due to potential for arcing.	Now	1	Slightly higher than conventional fabric filter.

[a]Footnotes are listed on pages 2-16 through 2-20

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TABLE 2-5. Concluded[a]

Abatement Method	Potential Process Application	Range of % Control	Application Limitation	Schedule	Ref	Cost -- (Initial Installed)
High temperature high pressure filtration	1000-2000°F particle laden gas streams currently requiring gas cooling	99.99%[2]	Further development and testing is needed prior to commercialization.	1982	29	Unknown at this time
Granular bed filter	High temperature application	80-90%	Collection by inertial impaction performance probably about equal to mechanical collectors/ scrubbers requires development.			High
HGMS magnetic separation	Steel making operations	90+% for submicron	Particulate must be magnetic	Unavailable now, research continuing.		

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[a]Footnotes are listed on pages 2-16 through 2-20

gas streams due to the potential for arcing. The range of control is expected to be up to 99.9 percent. The range of control for non-electrostatically augmented scrubbers is expected to range up to 99+ percent. The control efficiency for both will depend heavily on energy input.

High presssure, high temperature filtration technology using ceramic fibers is expected to become available by 1982. The control efficiency may range up to 99.99 percent for high temperature streams. However, further testing and development is needed prior to commercialization.

HGMS technology may become available by 1985. Its application to steel mills may enable 90+ percent control for submicron particles. Application of HGMS to other industries of processes is limited by the requirement that the particulates must be magnetic.

For fugitive emissions, the lowest achievable emission rates we identified are generally near the same level of control as the rates identified earlier by ESI. For industries such as stone quarries, the greatest control is afforded by the use of hoods and by ducting emissions to conventional control devices. Small filter units can be used at transfer and dump points to collect a major share of fugitives. Compared to other sources, control efficiences for sources such as quarries are limited more by the economics of ducting and hoods than by technological constraints.

Regarding fugitive emissions from paved and unpaved roads, a PEDCo. study concluded that since the rate of reentrainment of particulates by traffic was shown to be uncorrelated to the amount of material on a

street, reducing the amount of material by street cleaning might not consistently reduce particulate concentrations. (Several means of reducing material on streets are listed in Table 2-3). The control of mud and dirt carry-out from construction sites can be accomplished through sweeping and application of water; such control showed significant reductions in particulate concentrations.

FOOTNOTES TO TABLES

[1]Fabric Filter, general

A properly applied and operated barrier filter system will generally achieve a collection efficiency well in excess of 99.9 percent and often better than 99.99 percent. Manufacturers, however, will naturally be reluctant to guarantee this level. In emission calculations, use of the 99.9 percent rate obviously will result in a 10-fold increase in emissions over that for a 99.99 percent.

We believe that a 99.99 percent rate has been sufficiently shown to warrant its use in forecasting 1985 emission rates.

The intent of the listed percent efficiencies is to generalize the performance of each generic grouping of control equipment. It is apparent that each specific installations actual performance is a function of design, maintenance and operating history. The factors which are normally considered in an engineering design include but are not limited to the following:

- Particle size distribution
- Particle shape and surface characteristics
- Inlet mass loading and variation with time
- Gas temperature and composition
- Humidity of incoming stream
- Fabric availability and compatibility with the gas to be cleaned.

The percent efficiencies* (see note on accuracy of tables) listed are believed to be the nominal upper bound and are not to be construed as routinely achievable unless the installation is designed, maintained and operated in accordance with the best engineering practice.

To express the capability of fabric filters in terms of a grain discharge rate would strain the limits of credibility of this study. Estimating a grain discharge rate would require an assumption as to inlet grain loading on a mass basis as well as a particle size distribution. Using such assumed data and further assuming that the other process characteristics were properly accounted for in the design, an assumed outlet discharge rate could be defined. To attempt to generalize this parameter, however, is judged to be inappropriate because of the significant inaccuracies which would result from its eventual use in the EEA model.

Leakage around a barrier filter or penetration through it during a cleaning cycle is accepted as the primary contributor to emissions from this class of control equipment. The identification of this leakage with the expeditious correction of the problem (by more carefully securing the filter or modifying the cleaning routine) is the best means of control. The installation of opacity monitors on the discharge of each cell or

compartment is generally the best approach to rapid identification of this type of discharge problem. Through careful maintenance and operation the effect of this leakage can be reduced to an acceptable level.

In developing these tables, a question arose regarding what is included in particulate emissions. The resolution of the question has been elusive since each state or county (air pollution control district) can make its own definition. Generally two schools of thought exist:

a. Particulate emissions are those substances which are collected on the heated filter in an EPA Method 5 sampling train;

b. Particulate emissions are those substances which exist at some defined conditions (often 1 atm and 70°F) in either a liquid, solid or semisolid state. This definition requires the inclusion of some if not all of the impinger catch in an EPA Method 5 sampling train.

The definition selected will significantly influence the answer to this question. It should be remembered however, that in most instances water alone is not considered a pollutant.

[2]High Temperature Filtration

Particle control using ceramic fiber filtration is being developed for application in advanced coal combustion systems such as pressurized fluidized bed combustion. Part of this development includes methods for operating filter systems at high filtration velocities. These techniques will be applicable to high temperature applications at ambient pressures and to some conventional filter situations. Higher velocity filter systems will mean smaller filter installations which can be produced at lower cost. These effects will tend to offset higher filter element costs so high temperature filter units may not cost more than conventional filter systems.

[3]Note: For Scrubbers

The data presented in this table is intended to be a general review of available (now or by 1985) particle collection equipment. In reviewing the technical literature for scrubbers the following types were investigated:

- Gas atomized Spray (Venturi)
- Preformed Spray
- Mobile Bed (Turbulent Contact Absorbed Scrubbers)
- Condensed Steam Scrubbers (Flux Force Scrubbers)
- Electrostatically Augmented Scrubbers.

The predominate collection mechanism for high efficiency fine particle (less than 3 μm) collection is accepted to be inertial impaction although any of the following may also contribute to the overall collection efficiency of a given device:

- Interception
- Brownian diffusion
- Turbulent diffusion
- Gravitational settling
- Electrostatic Flux Force
- Diffusiophoretic Flux Force
- Thermophoretic Flux Force (not generally significant)
- Photophoretic Flux Force (not generally significant)

Since inertial impaction is the primary collection phenomena, collection efficiencies are directly dependent on energy input. Moreover, in reviewing the impaction parameter I,

$$I = \frac{C_c P_p D_p^2 V_j}{18 f D_j}$$

(from "Cascade Impactor Network," by R. E. Lee, Jr.. and S. Goranson, USEPA, 1972)

where:

P_p = true particle density, g/cm^3

D_p = particle diameter, cm

f = viscosity of fluid, g/cm-sec

V_j = relative velocity between particle and impaction surface cm/sec

D_j = diameter of jet

C_c = Cunningham correction factor.

It is seen that as the particle diameter decreases (assuming the droplet diameter and gas viscosity are constant) the relative velocity must increase in order to maintain or increase collection efficiencies. Relative velocities are achievable only by accelerating the droplet (preformed spray devices) or the gas (gas atomized spray devices). In either instance collection efficiency is strongly dependent on energy input.

Because of the large number of scrubber types and manufacturers it is beyond the intent of this table to offer design or performance parameters for all possible sources. The unique characteristics of each

source make such generalized data unusable. It is, however, suggested that within the cost range given (in 1978 dollars), efficiencies of up to 99+ percent are achievable on virtually all sources with technologies available now or by 1985.

Advanced scrubber types such as the Lone Star Steel Steam Hydro Scrubber, the TRW Charged Droplet Scrubber, APS Electrostatic Scrubber, and the UOP Mobile Bed Scrubber have been reviewed during the course of this study but their listing, or the listing of the numerous other types or manufacturers currently available would not affect the collection efficiencies given.

[4]Costs

The cost figures given are generalized installed system costs and are not intended to reflect actual ownership expenses. The total annualized cost of ownership would necessarily include depreciation, taxation, local labor costs, plant overhead allocations to pollution control and potential income from product recovery. Since these are often unique for each situation no attempt has been made to include these figures. However, a recent study (1976) concluded that the annual cost of operating a fabric filter or electrostatic precipitator was approximately 33 percent of the installed cost. Scrubbers designed for fine particle collection were reported to have an annual cost of $526 to $1051 per 1000 acfm/year. Installed cost given in tables is $0.50 to $7.00 acfm. Caution is suggested in using the generalized cost figures given because of the significant cost ranges likely to be encountered.

[5]Efficiency

Efficiency figures shown reflect the overall mass efficiencies which are felt to be generally achievable with the technologies listed. It is cautioned, however, that the efficiency obtained from a given device is a function of inlet particle size distribution, mass loading and variability of flowrate as well as the maintenance and operating history of both the process and the particulate control equipment. The proposed numbers are believed to be upper limits which are dependent upon a proper engineering design and regularly scheduled and performed maintenance program.

Application to fugitive particulate emissions -- In some cases we have shown 90 percent range of control for fabric filters and ESP. What we are trying to show here is the effect of not collecting all of the fugitive emissions. It might be argued that in that case a lower cost device such as cyclones, should be used. This would not be a reasonable approach since the most dangerous portion of the fugitive emission (the finer particles 2 μm) would be released back to the atmosphere.

[6]Fabric Filter Feasibility for Process Applications listed:

Fabric filters are listed in the table as the best applicable particle control technique for most processes. This conclusion needs to be qualified by an understanding of the limits on the application of this technology. Fabric filters can not be merely added to the duct system of many industrial processes. Temperature, humidity and gas composition all need to be evaluated and in some cases controlled to make a fabric filter operate satisfactorily. The intent of the listing is to suggest that with proper engineering design, if the objective is to achieve the highest collection efficiency possible, with a single control device, that a baghouse is the best available technology. The required gas conditioning upstream of the device may, however, require expenses which until recently would be considered prohibitive.

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NOTE to Bibliography:

This alphabetical listing is offered to summarize the documents reviewed during this preparation of the accompanying table.

SECTION 3

EMERGING TECHNOLOGIES FOR STATIONARY HYDROCARBON SOURCES

This section presents data on emerging hydrocarbon control techniques that are or may become commercially available by 1985. The emphasis is on identifying controls that may afford more emission reductions than available through the estimates of LAER used by the Agency in its earlier evaluation of the offset policy. Consequently, although cost of control is addressed in this report, it was not a criterion for selecting those technologies to be included here.

As with stationary particulate sources, the Office of Planning and Evaluation prepared lists of the major stationary hydrocarbon source in the 3 AQCR's (Houston, Philadelphia, and Chicago) being looked at in depth in the study on offset policy. Table 3-1 presents a list of these sources and processes.

Because control technology is more dynamic for hydrocarbons than for particulates, we present information on emerging hydrocarbon control techniques in a slightly different format than for particulates and rely more on textual description. A brief summary is presented as necessary for each process along with a discussion of the status and capability of control technologies. Information on control techniques is summarized in Table 3-6.

Findings

There are a range of hydrocarbon control techniques that offer the potential for reducing emissions through 1985 (and beyond). We believe we

TABLE 3-1. MAJOR HYDROCARBON SOURCES IN THE HOUSTON, PHILADELPHIA, AND CHICAGO AQCR'S (COMPILED FOR THIS STUDY BY THE OFFICE OF PLANNING AND EVALUATION)

HOUSTON	PHILADELPHIA	CHICAGO*
Ethylene	Surface coating, including:	Copper refining
High density polyethylene	- paper and allied products	Coke production
Low density polyethylene	- transportation equipment	Printing:
Acetaldehyde	- fabricated metals	- general solvent gravures
Petroleum Refining:	- miscellaneous plastic products	- general printing driers
- storage tanks	- all other surface coating	Surface coating:
Polyvinyl chloride**	Petroleum product:	- general painting
Glycerine**	- storage tanks	- general primer coating
Polypropylene**	Petroleum refining:	- ovencoating
	- process drains	- general adhesive coating
	- miscellaneous fugitive emissions	- general enamel coating
	Printing presses	

* OPE later directed the contractor to not address these sources unless they also occurred in the Houston or Philadelphia list.

** Emission Standards and Engineering Division (OAQPS) reviewed and was in agreement with the emission estimates used in the earlier offset study for polyvinyl chloride and glycerine. Consequently, these two processes were not considered further in this study. Beyond the data presented in this report for polyethylene, no data was available on polypropylene. ESED stated that because the manufacturing process is very similar to high density polyethylene, it is reasonable to expect similar emissions.

have identified the most significant of these through this study. The more important of these involve activated carbon and wet scrubbing. For ducted emissions, several manufacturers appear to have improved activated carbon for absorbing hydrocarbons at 90% efficiency or higher (excluding capture efficiency of the hooding and ducting). Publication rotogravure operations, for example, can be controlled with carbon systems having a recovery efficiency of 90% of the VOC entering the bed. In another example, Pura Siv-HR, a beaded activated carbon system, has cleaned a 10 ppm, 140,000 scfm stream to 1 ppm.

Modified wet scrubbing of organic vapors using surfactants holds potential for scrubbing low concentrations of solvent vapors. Experimental data shows organic removal efficiencies of up to 99%. Particularly high removal efficiencies were consistantly found for carbon tetrachloride. Studies are being extended to evaluate other hydrocarbons. When and whether this particular technology may become commercially available is uncertain as it is currently in the bench scale testing phase.

Union Carbide has developed a process for making low density polyethylene (LDPE) that offers reduced emissions. The process works by continuously feeding gaseous ethylene and a catalyst to a fluidized bed reactor at reactor pressures of only 100 to 200 psi compared to conventional process pressures of 30,000 to 50,000 psi. This reduced pressure offers potential for lower emissions than does a standard plant. In addition, the product is grandular rather than in pellet form, eliminating the need for molten LDPE in order to pelletize.

Fugitive emissions in a number of applications can be reduced by use of seal-less pumps and sealed valves. Use of these pumps and valves may be limited by space requirements and viscosity and size limits.

These and other control techniques are discussed in more detail in the following subsections according to process. Cost, efficiency, and applications data is presented for these processes wherever possible.

PROCESSES

ETHYLENE

Ethylene, propylene and butadiene are the most important olefins used for the production of petrochemicals. All are produced in various ratios by the cracking of feedstocks as different as ethane and crude oil.[1-5]

Gas feedstocks are common for U.S. ethylene production, with ethane supplying 53%.[6] Heavier feedstocks are playing a greater role in ethylene production as supplies of traditional feedstocks (ethane, LP-gas and naphtha) fail to keep pace with ethylene growth.[7] The same type of cracking plant and conditions are used for gas oils as those for naphtha.[8] Houston has ethylene plants composed of gas and liquid feedstock. Many of the new plants in the area are liquid feedstock plants. The major areas of concern at an ethylene plant are catalyst regeneration, the compression seal oil degassing area, loading and unloading, tank storage and fugitive emissions.

Fugitive emission sources such as valves, wastewater separators, pressure safety valves, cooling towers, pumps and mixers, and sampling are covered in later sections. Fugitive emissions from a 10^9 lb/yr plant flare system can be reduced with the installation of a back-up compressor. Outages due to compressor trips and checks, major maintenance and cleanups are significantly more frequent during the first five years of operation than thereafter. A back-up compressor system designed to handle 55% of the production level could decrease hydrocarbon emissions by approximately 180 ton/yr after the first four years of operation, and 320 ton/yr during the first four years of operation. These reductions are from estimated material losses to the flare based on annual trips and checks with a single compres-

sor train[9] and an assumed 95% flare efficiency during upsets. The installation of a second compressor train designed for 55% of a one-billion-pound-per-year ethylene plant requires an additional capital investment of $14,000,000 (estimated mid-1979 costs).[9] No other cost data was available relative to size of application.

Catalyst regeneration and the compression seal oil degassing area are located between the cracking furnace and the dripolene pyrolysis gasoline (DPG) unit, the major process area of an ethylene plant. Catalyst regeneration should be a two-step process. The first step should be precatalyst regeneration involving steam driven across the catalyst bed to the closed quench system. This step removes the oil and heavy hydrocarbon concentrations before actual regeneration. This closed precatalyst regeneration step can continue for days depending on previous operational variables. The total organic carbon (TOC) from the steam condensate should be closely checked periodically. When the condensate TOC level reaches approximately 200 to 500 ppm, it is time for the second step. This step is the actual catalyst regeneration of a steam and air burn across the catalyst bed and vented to the atmosphere.

Charge gas compression seal oil degassing area discharge can be eliminated by being piped to a flare, piped to a carbon adsorption system or recycled to the quench tower.

POLYETHYLENE

Polyethylene is produced in two forms, high density polyethylene (HDPE) and low density polyethylene (LDPE). Low density polyethylene is produced by polymerizing ethylene in high pressure reactors at 30,000 to 50,000 psi; HDPE is produced by polymerizing ethylene dissolved in a sol-

vent at up to 350 psi. Volatile organic emissions from the manufacture of HDPE are 68 lb/ton of product and 32 lb/ton of product for LDPE.[10] An EPA-recommended LAER factor for HDPE is 5 lb/ton of product and 2 lb/ton of product for LDPE.[11]

Union Carbide has announced a new process for making LDPE that requires only half the capital and a quarter of the energy needed by current methods. Union Carbide will install nearly a billion pounds a year of new capacity based on the new low pressure process by 1982. Union Carbide also plans to offer the new process to other polyethylene producers worldwide through licensing agreements. This process works by continuously feeding gaseous ethylene and a catalyst to a fluidized bed reactor at reactor pressures of only 100 to 300 psi compared to conventional LDPE process pressure of 30,000 to 50,000 psi.[12]

This new LDPE process was run for over two years before being announced. This process has the potential of a lower LAER than a standard LDPE plant because of a reduction of pressures throughout the system, and the product is granular rather than pellet form. This also eliminates the need for molten LDPE in order to pelletize.[13]

Fugitive leaks are an important source of emissions from the LDPE process. The Texas Air Control Board requires LDPE plants to install double mechanical seals on pumps, to vent emergency and presure relief valves to a flare, and to route compressor emissions back to the process and into a control device. However, fugitive emissions could still be present from such uncontrolled sources as valves, flanges and sampling.[11] Separate sections follow which pertain to further hydrocarbon controls on polyethylene plants.

ACETALDEHYDE

Acetaldehyde can be produced from the single stage process, the two stage process, a vapor phase catalytic oxidation of ethylene, and the non-catalyzed oxidation of propane and/or butane.[14] One of the main sources of air pollutants in the single stage process is off-gas from the water scrubber. This source of pollution can be treated by incineration. Incineration can also be used for the off-gas scrubber associated with the two-stage process. Many of the emissions from plants of this type are associated with the cooling towers, wastewater separators, sampling, laboratories, loading and unloading, valves, pumps, storage tanks, etc., as discussed later. Storage tank reduction of hydrocarbons is discussed under the petroleum storage tank section.

PETROLEUM REFINING

Catalytic Cracking

All of the catalytic cracking processes currently in use can be classified as either fluidized bed catalytic cracking (FCC) or moving bed catalytic cracking (TCC).[10] Hydrocarbon and carbon monoxide (CO) emissions are the major pollutants during catalyst regeneration.

Hydrocarbon emissions from FCC regeneration average 220 lb/1000 bbl. with fresh cat cracker feed; hydrocarbon emissions from TCC regenerators average 87 lb/1000 bbl. with fresh cat cracker feed.[15] Hydrocarbon emissions from FCC regenerators can be reduced 0 to 20 lb/1000 bbl. of feed with the use of CO boilers.[16]

Moving-bed catalytic cracking regenerators produce significantly less flue gas than FCC regenerators and may not justify using a CO boiler. These emissions may be incinerated in a process heater box or smokeless

flare and thus reduced to negligible quantities.[10] A new method of control consists of high temperature operation of the TCC regenerator itself. New designs operate at 1400°F with slight excess air, converting 98+% of the CO to CO_2 and completely oxidizing all hydrocarbons.[17,18] Existing regenerators often cannot withstand the high temperature necessary to burn off the coke, and to do so would necessitate replacement with new regenerators.

Valves

Emissions from valves have resulted in the passage of more stringent regulations regarding the handling of hazardous and toxic fluids. This has led to the manufacture of no-leak ball valves to meet those regulations. The nuclear industry, which first developed the no-leak valve, has also produced no-leak valves with high pressure ratings (resulting in sealed double "bellows" or "bonnets" to be attached to valves [Figure 3-1]). Sealed valves are now made to comply with conventional pressure ratings.

Truflo, one of the manufacturers of sealed ball valves, produces sealed ball valves which range in size from 0.5 in. to 76 in. nominal bore, based on a standard Truflo top entry ball valve. This size range enables any existing Truflo ball valve to be easily converted to a sealed valve by changing the bonnet assembly. The sealed ball valve could also be adapted to fit on another manufacturer's ball valves of a certain type. Activated ball valves with this bonnet assembly are in the experimental stage but should be available soon.[19,20] Due to the design of the ball valve seal, more space is used than typically required. Cost of the sealed ball valve is about 40-50% more than a regular ball valve. Large scale production of this valve would reduce the cost.[19]

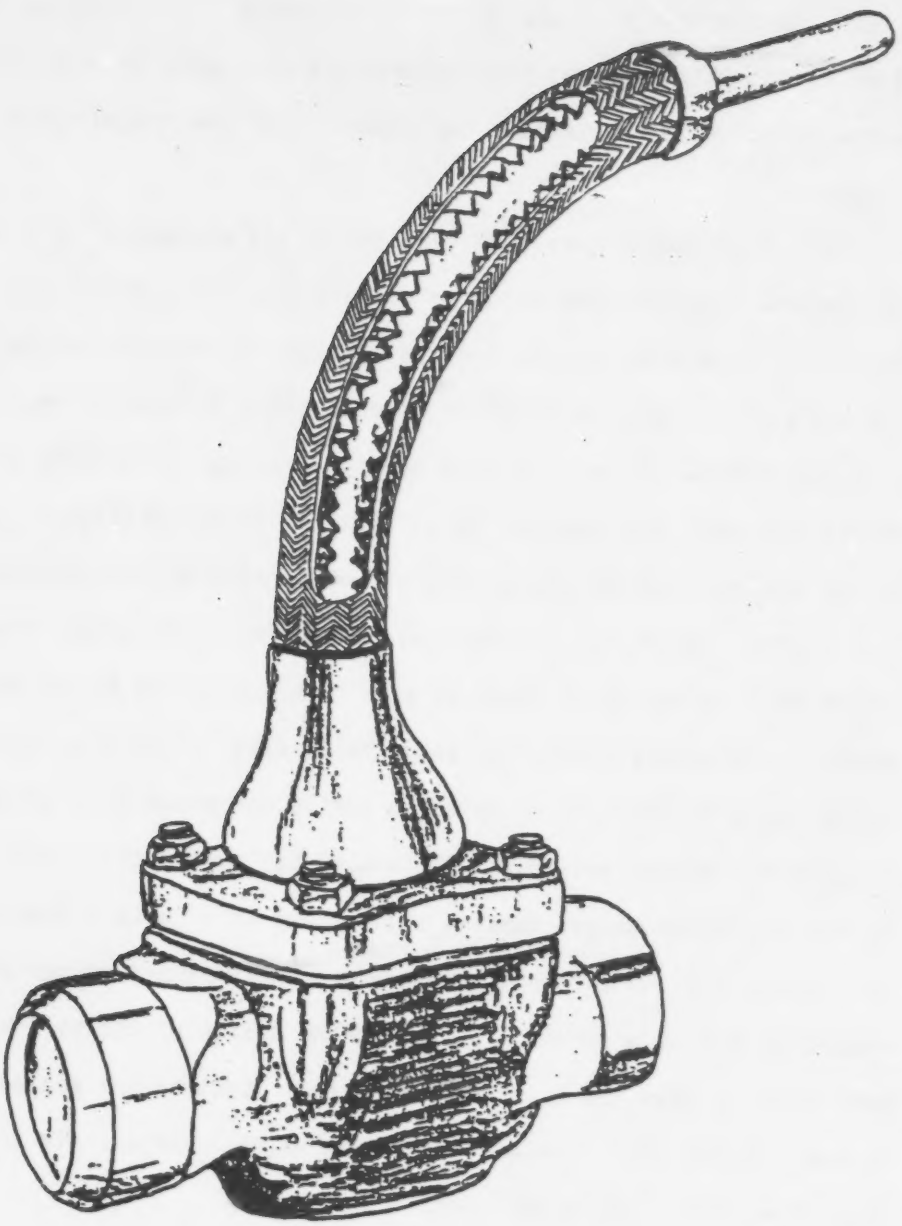

Figure 3-1. "Bonnet" sealed valve.

A two-inch Truflo sealed ball valve in a two-inch line which handled recovered vinyl chloride monomer was tested for eight months at the Imperial Chemical Industries Limited Plastics Division in Welwyn Garden City, Hertfordshire, England. This was a difficult valve application due to the inherent "build-up" which occurs inside the pipeline system. The valve was operated two or three times per week during the eight months with no leaks to the atmosphere.[21] A sealed ball valve is currently being used in England by Stavely Chemicals on a phosgene application.[20]

The WKM valve company has for 1½ years made bellows-type control valves for nuclear power plants. Some of their valves have been sent recently for use in the LaSalle Nuclear Power Plant. None of their bellows valves are currently in service. Their sealed valves are made in 1 in. to 4 in. sizes with pressure ratings of about 1,000 psia. This type of pressure usually requires a double bellows.[22]

It should be emphasized that there are more manufacturers of sealed ball valves that have not been named. Sealed valves are presently available for only limited applications.

Wastewater Separators

Contaminated wastewater is collected in the process drain system and usually directed to a wastewater treatment system. The collection system in most refineries and petrochemical plants is either an American Petroleum Institute (API) separator or, in some cases, a corrugated plate interceptor (CPI) where the oil and water are separated.

All units of this type should be either a CPI, which is controlled by a fixed roof cover, or an API separator with a solid cover and all openings sealed. Each should have only breathing ports under a slight vacuum which

ejects to the flare or a hydrocarbon removal system thus completely eliminating fugitive emissions from this source, as well as stripping a small portion of the light hydrocarbons before being stripped in the biological wastewater aeration system.

Another system of eliminating essentially all hydrocarbons from releasing into the atmosphere at the separator or in the biological wastewater aeration system is by stripping (vacuum or steam) the wastewater prior to entering the ponds to recover organics.[23]

Loading and Unloading

One source of fugitive emissions to the atmosphere is due to procedures followed during the loading and unloading of petroleum and petrochemical products. In order to prevent this problem a closed hydrocarbon loading and unloading system can be installed (Figure 3-2). This would replace complete reliance upon the operator-oriented systems such as the slip tube and premetered loading systems. An example would be the use of an elevated overfill drum with an automatic level controller connected to the loading pump. The overfill drum would vent gases into the process or the flare system while loading, and the automatic level controller shuts off the loading pump when overloading.

All hydrocarbon loading and unloading systems should have quick connect couplings. The loading lines up to these couplings should have a valve connected to the flare system which allows line pressure to be properly released when needed. A small portion of the line filled with vapors and some liquid hydrocarbons left between the two couplings emits to the atmosphere when disconnected. These liquid and/or gaseous hydrocarbons can be displaced with unreactive methane before disconnecting, by filling the area

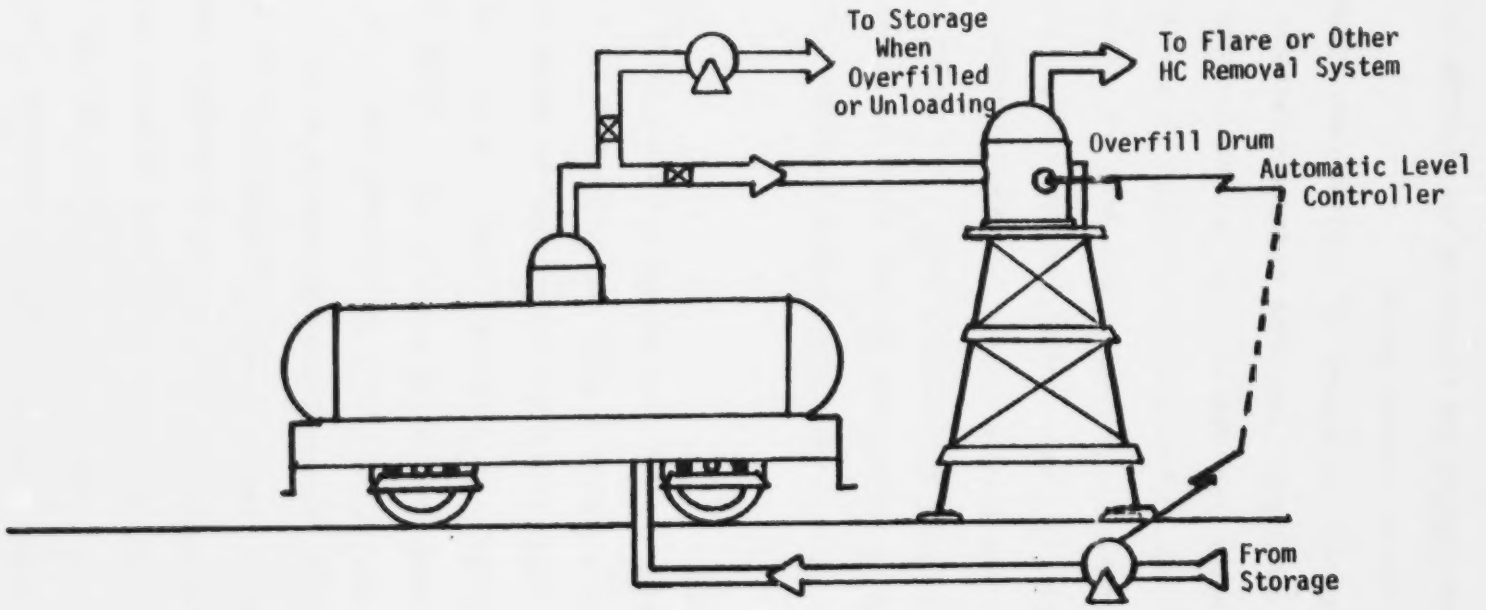

Figure 3-2. Closed loading and unloading system.

between the valves with methane and evacuating the reactive hydrocarbons to a flare or other hydrocarbon removal system.

A new carbon presently being used for gasoline vapor recovery called VPLF-3 has been made by Calgon. According to the manufacturer this particular carbon is designed to trap organics with less regeneration energy input. The energy savings is due to low retentivity. Normally a strongly adsorbed hydrocarbon requires more energy to be removed from the carbon. In given conditions, this carbon will have a higher working capacity and will require less energy for each regeneration cycle. For gasoline removal, it achieves two times more removal with only 20% more cost. This carbon has been tested for 1½ years in gasoline applications at bulk terminals and one pound canisters on automobiles. This carbon could be used for other hydrocarbon applications.[24]

Pressure Safety Valves

The insertion of a rupture disc between the block valve and pressure safety valve (PSV) is a procedure which has been around for a while to prevent hydrocarbon leaks from PSV's which cannot be vented to a flare. The normal safety valve is not absolutely tight if a valve has been tripped; this situation increases the leakage quantity due to damage in the valve seat. The problem has been mainly in knowing when there is a leak since PSV's are in relatively inaccessible areas, such as on top of reactors, columns and pressurized storage vessels. An easy check can be made by the process or tank farm operator, if a thin tube is inserted between the PSV and the rupture disc and leads to a ground level pressure gauge. On tank farms this gauge could be next to the normal system employed for "gauging" tanks. Gauge tank readings could include the PSV gauge. Various configura-

tions can be made, but the purpose is to install an easy system in which normal operating procedures are used to detect hydrocarbon leaks.

Cooling Tower

During petroleum refining and petrochemical processes, volatile organics from heat exchangers may leak into the cooling water system. These organics are then stripped in the cooling tower. Hydrocarbon emissions from cooling towers in petroleum refineries have been estimated to be 6 $lb/10^6$ gal. of cooling water. It is emphasized that these emissions vary widely.[10]

A continuous total organic carbon (TOC) analyzer system can be placed in the cooling tower water return collection system at each of the heat exchangers. A large flash drum can be placed in the main cooling water return header. The flashing area can be under a vacuum which ejects to the flare or a hydrocarbon removal system.

Another way of reducing hydrocarbon and other forms of pollution is by the use of air cooled heat exchangers. This "dry cooling tower" does not consume any water thus eliminating problems with effluent water or heating of rivers. This type of dry air cooled heat can be used in all applications in which heat is to be transferred from processes to the surrounding air, provided the required temperature of the product is not less than 37°-50°F above the maximum ambient air temperature.[25]

Pumps and Mixers

Pumps can leak at the point of contact between the moving shaft and the stationary casing. If volatile, the leaked product will evaporate into the atmosphere.

The loss from mechanical rotary seals can be eliminated by using seal-less or magnetic pumps. Double mechanical seals have been in use for some hazardous pollutants such as vinyl chloride. Seal-less and magnetic pumps are being used for extremely toxic materials such as phosgene, arsenic trioxide, chlorine gas, and others. Seal-less and magnetic pumps do not rely on an inert fluid between two seals or venting the volatile vapors between the seals to a vapor recovery system to ensure complete fugitive emission control.

Seal-less pumps are now made which are cost competitive with double mechanical seal pumps. Crane Company manufactures a seal-less pump which is used to transfer non-hazardous materials such as inks that are merely messy if leaked. This series of seal-less pumps is called "Dynapump."[26] Their range in sizes and costs are in Table 3-2.

Crane Company sells a seal-less pump called "Chempump." The Chempump Division has been in business for about 25 years and has approximately two-thirds of the leak proof pump market. Chempump has the nuclear N-stamp approval for all three nuclear levels. This pump is not considered a booster pump. Due to the design, the pump is submersible. An application that is now being used with frequency is for heat transfer oil at 700-800°F. The maximum pump temperature is 1,000°F. Seal-less pumps are being looked at as replacements for single and double mechanical sealed pumps when a seal's maintenance problem arises.[26]

Chempump must have proper periodic preventive maintenance because two bearings which support the motor should be periodically replaced. If proper maintenance is not performed, not only do the bearings go bad, but the most expensive parts of the pump must be replaced.[26] A range of sizes and costs are in Table 3-2.

TABLE 3-2. ZERO LEAKAGE PUMP COSTS

Name	Type	Capacity	Head or psi	Construction Material	Cost	Cost Comparison*
Dynapump[30]	Seal less	10-15 gpm	20 ft.	304 stainless	$200-$300	[a]very competitive [b]less expensive [c]less expensive
J series[30]	Seal less	30-40 gpm	70-80 ft.	316 stainless	$1,000-$1,200	[a]higher [b]slightly higher [c]competitive
		100-140 gpm	70-80 ft.	316 stainless	$1,400-$1,600	same as above
Chempump[30]	Seal less	30-40 gpm	70-80 ft.	316 stainless	$1,500-$1,600	[a]not competitive [b]higher [c]competitive
		30-40 gpm	150 ft.	316 stainless	$2,000-$2,200	same as above
		100-140 gpm	70-80 ft.	316 stainless	$2,100-$2,400	same as above
		150 gpm	150 ft.	316 stainless	$4,000-$5,000	[a]not competitive [b]not competitive [c]20% to 25% higher capital cost
		400-500 gpm	200-250 ft.	316 stainless	$11,000	[a]not competitive [b]not competitive [c]not competitive
Eastern[33]	Magnetic	180 gpm	10 ft.	plastic	$3,500	no comparisons made
		30 gpm	100 ft.	plastic	$3,500	no comparisons made
Kontro[32]	Magnetic	0.5 to 40 gpm	100 ft.	steel	$2,000	no comparisons made
		750 gpm	200 ft.	steel	$8,000-$10,000	no comparisons made
Pulsafeeder[33]	Diaphragm	0.13 gpm	95 psi	316 steel	$485	20% to 25% higher than a packed plunger type pump
		25 gpm	90 psi	316 steel	$6,200	20% to 25% higher than a packed plunger type pump

Comparisons are in this order: [a]comparison with packed or single seal ductile iron pump and motor assembly
[b]comparison with same type steel single seal pump and motor assembly
[c]comparison wtih same type steel double mechanical seal pump and motor assembly

Magnetic drive pumps operate on a magnet-to-magnet drive with no seals. A drive magnet is located on the rear rotor hub of the pump wheel and a drive magnet is located outside the pump housing. These pumps are driven by a standard electric motor. To drive the pump, a special coupling is used which will prevent the full rotation of the magnetic coupling.[27]

The LFE Division of Fluid Controls, Hamden, Conn. makes a small plastic magnetic drive pump named Eastern. The limits of this pump are not more than 100 ft. of head and no temperature over 175°F.[28] (See Table 3-2)

Another magnetic drive pump is made in England and sold throughout the U.S. by Kontro Company, Inc. This magnetic drive pump has been sold for 20 years. The major applications of this pump have been in handling hazardous toxic materials, explosive applications and nuclear areas for radioactive waste. This pump does not have a nuclear N-stamp approval. Due to the inherent design, a magnetic drive pump can handle slightly more abrasive fluids than seal-less drive pumps, but is not an abrasive fluid pump.[28]

Diaphragm pumps are zero leakage pumps for metering or proportioning. One brand of diaphragm pump has been made for about 35 years and has had extensive service throughout industry. This pump is presently being used in polyvinyl chloride (PVC) plants. This zero leakage pump normally replaces a packed plunger type pump. One major problem is that as the viscosity of the pumped fluid goes above 200 centipoise, the hp increases rapidly.[29]

Static mixers (in-line mixers) should replace open vessel and mechanical seal and propellar continuous mixing applications. Batch mixing applications should use a double mechanical seal and propellar type arrangement. Static mixers if applied correctly have zero leaks.

Sampling

Sampling procedures should be designed with a minimum of emissions to the atmosphere. This could be achieved by establishing a closed sampling loop. When a hydrocarbon stream or vessel is sampled for analysis, the sample flask can be purged back to the process stream rather than to the atmosphere. The sample connections can be placed so that the hydrocarbons flow from the process into one end of the sample flask and from the other end of the sample flask back into the process at a second point. Each end of the sample flask is attached to the sample point with quick-connect couplings. The flask valves and the process valves are opened to purge a fresh sample from the process stream through the flask and back to the process stream. Once the flask is purged and filled, the process valves and the flask valves are closed. The short sections of pipe between the flask and process valves can then be purged with inert gas to a recovery system or to a control device.[23]

After the sample has been taken to the laboratory and is ready to be discarded, the excess sample should be purged into a hood connected to the flare or other vapor recovery device.

Miscellaneous Options for Petroleum and Petrochemical Plants

1. A catalytic incineration system has been developed for treating organic emissions that permits lower temperatures and fuel costs than do thermal or flame incineration techniques.

The inherent advantages of catalytic incineration with respect to fuel cost and materials of construction led Air Resources, Inc. and the Harshaw Chemical Co. to undertake a joint development program aimed at overcoming the disadvantages of catalysts. This work resulted in a catalytic incinera-

tion system for treating hydrocarbon and chlorinated hydrocarbon emissions at lower temperatures and fuel costs than thermal or flame incineration. This system is comprised of the "Econ-Acat" catalyst which is immune to halogen suppression and the "Econ-Abator" incinerator.[30]

Two commercial units have been designed and placed in operation. One served temporarily a barge loading operation in which noxious organic materials including tertiary butyl mercaptan were released. The second unit destroyed chlorinated hydrocarbons from a chemical manufacturing operation and includes provisions for by-product HCl recovery.[30]

2. All large pumps, compressors and motor valves can be connected to a centrally located multipoint analyzer. In this manner records and checks of slow leaks can be watched to determine the time and frequency of required maintenance. This type of system is also useful in showing Occupational Safety and Health Administration (OSHA) compliance.

3. A lightweight air collection system can be installed around compressors, pumps, motor valves, etc. This type of system could only be used where the collected air is capable of attaining very low levels of hydrocarbons in order to prevent the possibility of explosion. This system could consist of an air mover with the exhaust blowing into the intake air of a boiler or other combustion unit. The air mover would have to be designed to prevent flashback. The air mover exhaust could only supply part of the combustion unit intake air and could not be directly connected. This would prevent any accidental shutdown of a boiler due to such problems as air mover, or duct work, problems. Only a few systems could be connected to each boiler air intake. This type of system could be adapted to polyethylene product storage bins.

4. Oxy Catalyst has developed a control system for use on small hydrocarbon streams. This system consists of a muffler type arrangement, a catalyst and electric preheater placed on a stream. The catalyst operates in the 500-600°F range with 99% hydrocarbon removal. This system is available now at a cost of $4,500 for a 100 SCFM input with 100 ppm hydrocarbons.[31]

PETROLEUM STORAGE TANKS

The New Source Performance Standards (NSPS) require all new tanks of over 40,000 gal. capacity storing petroleum liquids which have volatility greater than 10.5 kPa (1.5 psia) to be of floating roof design or to have a vapor recovery system.[32] TACB Regulations V and VI, which control existing and newly constructed tanks in the Houston area, require nearly all refinery and petrochemical storage tanks to have floating roofs for materials up to 11.0 psia. It is becoming evident from past TACB permits that double seals are required on new construction tanks, thus leaving a more limited choice of types of hydrocarbon emission controls for storage tanks. Two additional controls could be added to the existing floating roofs:

1. Installation of a secondary seal which spans the rim space from the floating roof to the shell is more effective than a secondary seal which rides the seal shoes only (Figure 3-3). This is true unless the primary seal is demonstrated to be "leak tight" by pressure testing. This control is the result of emission tests using Chicago Bridge and Iron's (CBI) SR-1 metallic primary seals compared to various types of secondary seals.[33]

2. Another control consists of installation of an accordian style tank insert that reduces emissions from storage to only permeation losses through the liner. Tests conducted on 1 ft. square pouches with gasoline

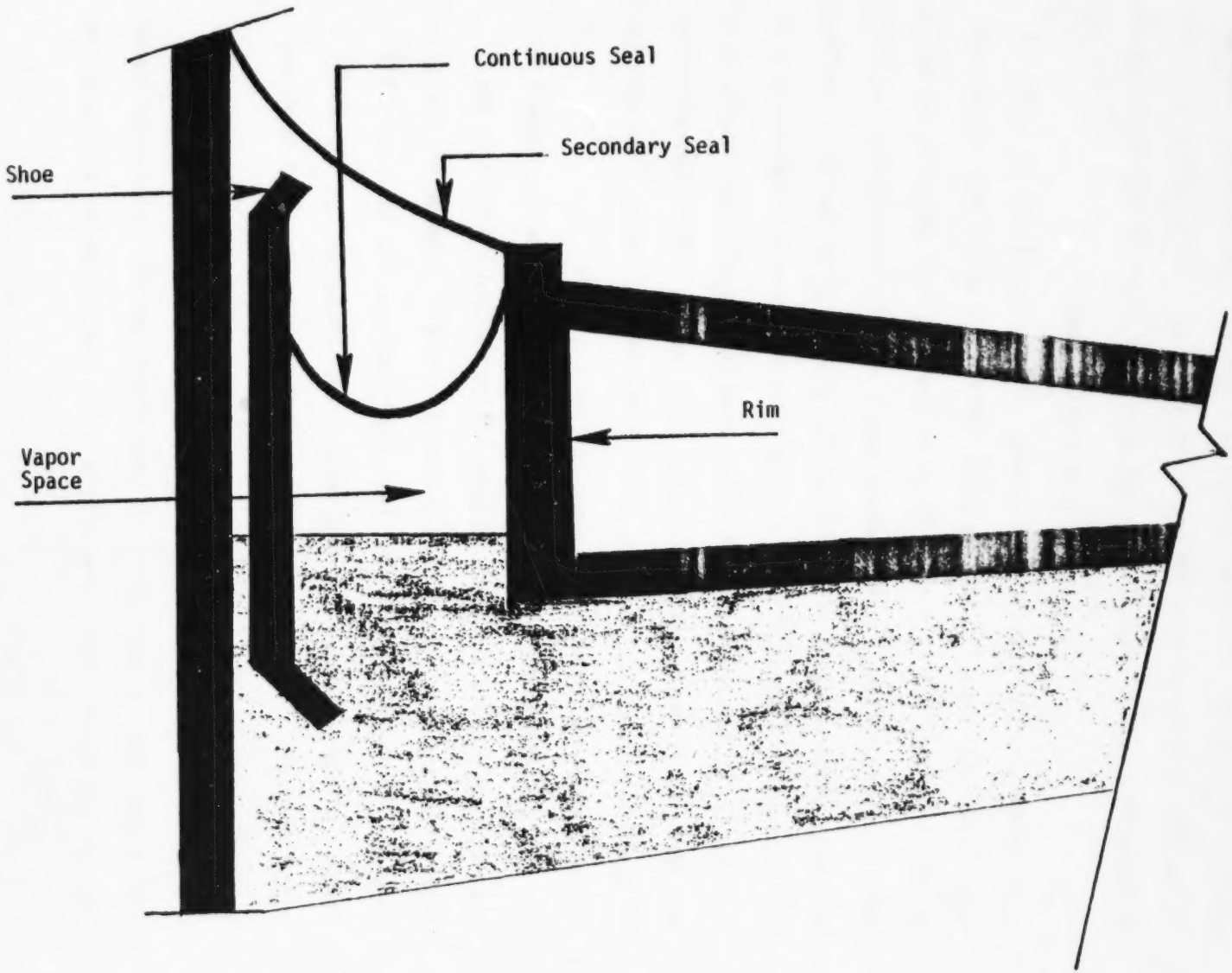

Figure 3-3. Type of secondary seal.

have shown a permeation gasoline loss rate of 0.04 to 0.05 g/sq. ft. of liner/day. There are no breathing or working losses because of the physical characteristics of the liner insertion. Tests are now being made with gasoline on a tank 6' in height and 6' in diameter. A few tests have also been made with alcohol and other liquids showing the same range of loss as gasoline.[34,35]

Retrofitting this insert into an existing 40 ft. ht. x 100 ft. d. floating roof tank would cost approximately $30,000. The cost of retrofitting a 40 ft. ht. x 100 ft. d. fixed roof tank without a floating roof would be about $40,000.[35] The tank being retrofitted does not have to be "round" due to the flexibility of the insert, thus eliminating most of the problems associated with retrofitting a tight sealed floating roof. Cost extrapolation beyond this size of tank is estimated to be proportional to the size of the tank.

PESTICIDE AND TOXIC CHEMICAL PLANTS

A microwave-induced oxygen plasma has been applied successfully for detoxification of pesticides and hazardous wastes. For details of the microwave plasma process, reference 52 may be consulted. Substances treated included polychlorinated biphenyls (PCB), phenylmercuric acetate (PMA) solution, methyl bromide, malathion, a polyaromatic dye mixture, and kepone. These materials all showed a greater than 99% conversion. Actual tests were run at a feed rate between 0.4 to 6.5 lb/hr. The potential for resource recovery was demonstrated for a PMA pesticide, which yielded metallic mercury as a salable product. Scale-up to a pilot level throughput of 10-30 lb/hr will be tested. Further expansion to 50-100 lb/hr is envisioned as feasible with current technology.[36]

For the determination of process costs for projected future 50-100 lb/hr plasma systems, an accurate assessment is difficult. However, where the object is to show the economic viability of the approach, it is possible to calculate values that can be derived from known process variables and estimated oxygen, electrical, and related costs.[36]

The material used for the calculation was phenylmercuric acetate, first, because it was considered refractory or difficult to decompose safely and completely, and second, because it had the potential for recovery of the mercury values in the metallic state.[36]

The following assumptions are listed as part of the estimated costs:[36]

Capital costs:	$100,000 per unit, 2 units in use
Electrical costs:	$0.015 kWh, industrial rate
Liquid oxygen costs:	$0.005/SCF, large volume usage. Add $3000/yr, storage fee
Labor costs:	$9/hr, one-man operation of two automated units
Credit for metallic mercury:	$1.50/lb

A standard 330-day/hr, three-shift operation is used. Throughput is 50 lb/yr per unit, or 792,000 lb/yr. The process variables related to PMA-30 on a per pound basis were for oxygen, 4.3 SCF, and electric line power, 1.6 kWh. The calculated costs are as follows:[36]

Variable costs

Operating labor	$71,280
Oxygen	20,028
Electricity	19,008
Maintenance (4% of investment)	8,000

Fixed costs	
Capital recovery (10 yr--7%)	28,480
Taxes and insurance (2%)	4,000
Total annual costs	$150,976
Cost per pound treated	$0.19

Based on recovery and sale of the metallic mercury, a net profit of $0.085/lb is derived.[36]

ROTOGRAVURE PRINTING

Printing is the transfer of an image directly or by intermediate surfaces from an image surface to the print surface. The image area of a gravure press is recessed relative to the non-image area. A very fluid ink fills the image area and is scraped off the non-image area with a "doctor knife." The image is transferred directly to the printing surface. When the process is roll-fed, it is known as "rotogravure."[37]

Rotogravure inks contain 40 to 80 percent solvent which may be an alcohol, aliphatic naphtha, aromatic hydrocarbon, ester, glycol-ether, ketone, nitroparaffin, or water. The inks are dried at 100-250°F.[37]

Although all rotogravure presses are the same, there are two principal rotogravure press uses:

1. Publication presses - magazines, etc.
2. Packaging presses - printing and coating of packaging materials.

The principal emission sources are the dryers and the ink fountains. Publication rotogravure presses use water-insoluble solvents, such as toluene; therefore, the solvent can be separated from condensed steam by decantation.

Publication rotogravure operations can be controlled by carbon adsorption systems with a capture efficiency of 75-85 percent of the VOC emitted from the printing units and the dryers. The carbon recovery system can be operated with a recovery efficiency of 90 percent of the VOC entering the carbon beds. An overall emission reduction efficiency of 75 percent can thus be achieved.[38]

Packaging rotogravure printing operations can be controlled by incineration systems with an expected capture efficiency of 70-80 percent and a combustion efficiency of 90 percent. An overall emission reduction efficiency of 65 percent can thus be achieved.[38]

Some rotogravure packaging printing operations with less demanding quality requirements can use water-borne inks. Most water-borne inks contain some VOC as a co-solvent. Emission limits comparable to carbon adsorption and incineration can be achieved if the solvent portion of the ink consists of 75 volume percent water and 25 volume percent organic solvent.[38]

Costs associated with thermal incineration, pebble bed incineration and carbon adsorption are shown in Figures 3-4 and 3-5 and Tables 3-3 and 3-4.

Modified wet scrubbing of organic vapors using surfactants holds a potential for scrubbing low concentrations of solvent vapors. Due to its present state of the art, it is unknown when this control would be available. Experiments are now being made using water with surface active agents as the scrubbing medium. Experimental data on removal concentrations obtained from static studies and pilot scale investigations have been gathered. Organic removal efficiencies using a number of the surfactants screened were observed up to 99%. Surfactants exhibiting high foaming

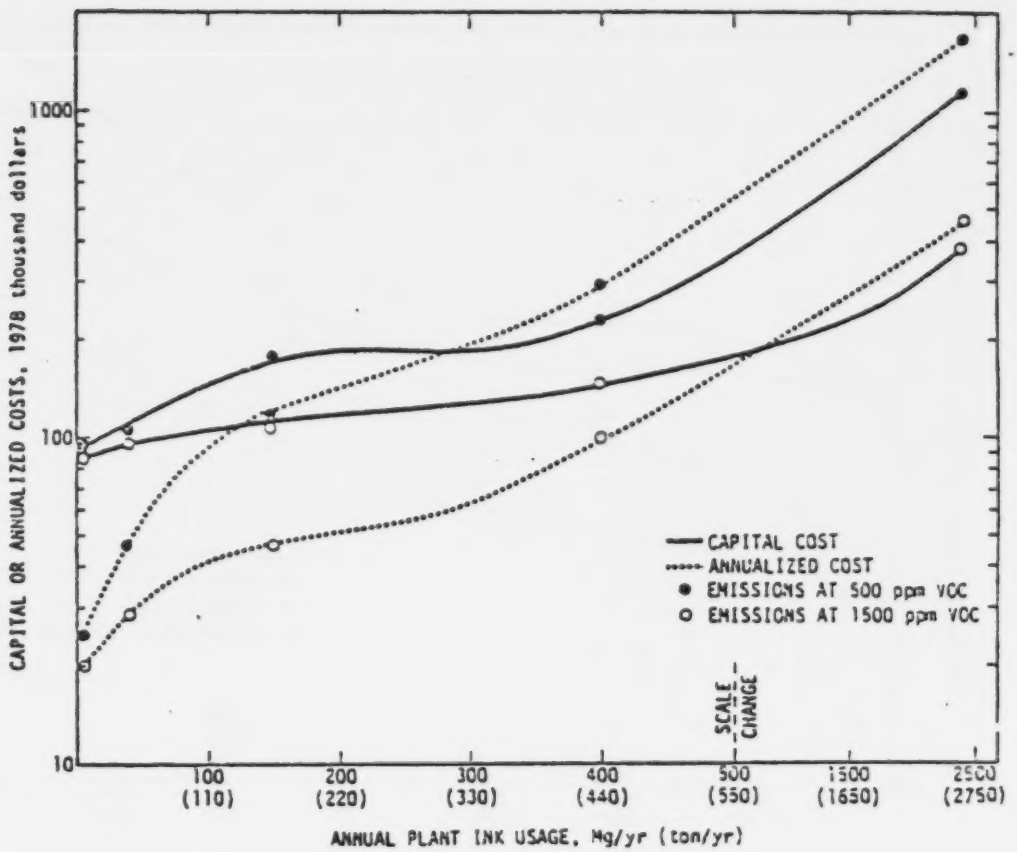

Figure 3-4. Capital and annualized costs of thermal incinerator without heat recovery for VOC control at existing graphic arts plant using flexographic and rotogravure printing process for packaging.

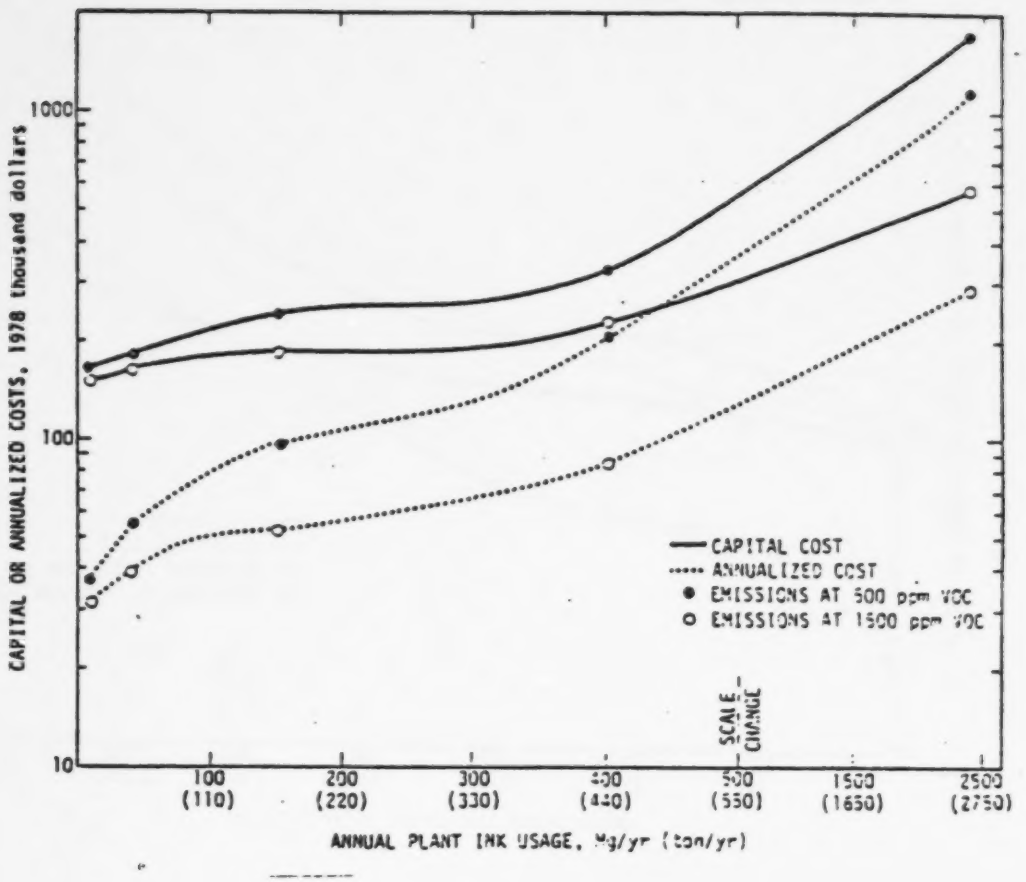

Figure 3-5. Capital and annualized costs of thermal incinerator with 50% primary heat recovery for VOC control at existing graphic arts plant using flexographic and rotogravure printing process for packaging.

TABLE 3-3. COST OF VOC CONTROL BY PEBBLE BED INCINERATOR[a,b,c]

(Mid-1978 dollars)

Plant size ink use, Mg/yr (tons/yr)	VOC concentration, ppm	Installed capital cost, $	Direct operating cost, $/yr	Annualized capital charges, $/yr	Total annualized cost, $/yr	VOC controlled, Mg/yr (tons/yr)	Cost-effectiveness, $/Mg ($/ton) VOC controlled
7.0 (7.7)	500	121,000	3,100	24,500	27,600	2.98 (3.29)	9,260 (8,400)
	1,500	118,000	2,700	23,900	26,600	2.98 (3.29)	8.930 (8,100)
40 (44)	500	146,000	7,200	29,600	36,800	17.82 (19.64)	2,070 (1,880)
	1,500	135,000	4,400	27,400	31,800	17.82 (19.64)	1.790 (1,620)
150 (165)	500	268,000	13,900	54,400	68,300	59.13 (65.18)	1,160 (1,050)
	1,500	167,000	4,600	33,900	38,500	59.13 (65.18)	650 (590)
400 (440)	500	391,000	34,900	79,300	114,000	177.3 (195.4)	640 (580)
	1,500	202,000	6,900	41,000	47,900	177.3 (195.4)	270 (250)
2500 (2750)	500	1,500,000	173,500	304,200	478,000	1,008 (1,111)	470 (430)
	1,500	585,000	11,600	118,600	130,000	1,008 (1,111)	130 (120)

[a]Taken from reference 38.

[b]Designed for 85% primary heat recovery.

[c]Costs based on 90% device control efficiency; however, according to a vendor, a pebble bed incinerator can remove as much as 98 to 99% of the VOC.

TABLE 3-4. COST OF VOC CONTROL BY CARBON ADSORBER FOR PUBLICATIONS ROTAGRAVURE PRINTING[a]

(Mid-1978 dollars)

	Plant using 3500 Mg (3860 tons) of ink per yr		Plant using 7000 Mg (7720 tons) of ink per yr	
	1,200 ppm[a]	2,400 ppm[a]	1,200 ppm[b]	2,400 ppm[b]
Equipment cost[b]	338,000	185,000	608,000	338,000
Installed capital cost[b]	701,000	435,000	1,262,000	701,000
Direct operating cost	100,800	82,900	192,100	156,400
Recovered solvent (credit)	-170,100	-170,100	-340,200	-340,200
Annualized capital charges	142,100	88,200	255,900	142,100
Total annualized cost	72,800	1,000	107,800	-41,700
Pollutants controlled at 90% control device efficiency, Mg/yr (tons/yr)	1,431 (1,575)	1,431 (1,575)	2,862 (3,150)	2,862 (3,150)
Cost-effectiveness of pollutant controlled, $/Mg ($/ton)	51 (46)	0.70 (0.63)	38 (34)	-15 (-13)

[a]Taken from Reference 38.

[b]VOC concentration by volume in emissions gas stream.

properties were those that showed the greatest removal values. Particularly high removals were consistently found for carbon tetrachloride and studies are being extended to evaluate removal of other hydrocarbons.[39] No data is available on whether the adsorbed VOC can be removed from the scrubber liquor. Selected maximum removals obtained are in Table 3-5.

Union Carbide has started marketing a fluid bed carbon adsorber called Pura Siv based on Japanese technology. This system is based on beaded activated carbon which, because of inherent strength and spherical shape, has fluidity characteristics approaching those of a liquid, and resistance to attrition far greater than that of granular activated carbon.[40]

The first commercial installation was in Japan in 1972. The first U.S. commercialization is to go on-line in December 1978, at the Ford Motor Co. Their application is a pilot plant test for control of emissions from spray coating autos. Pura Siv-HR has been used at a Toyota Motor Plant in Japan to control odors from a casting operation on a 140,000 scfm stream of 10 ppm hydrocarbons and cleaning to one ppm. This is a 90% removal with a very low concentration. Pura Siv-HR could be used for solvents, automotive coatings, adhesives coatings, and chlorinated hydrocarbon removal.[41]

Cost of Pura Siv-HR is dependent on flow, concentration and type of hydrocarbon to be removed.[41]

- approx. $100/scfm low flow high concentrate oxygenated solvents
- approx. $5/scfm high flow low concentrate aromatic solvents

Catalytic oxidation of pollutants from printing ink drying ovens can be achieved through the use of an automated catalytic incinerator. This system is capable of 95 percent or greater hydrocarbon conversion efficiency from ink drying oven exhaust.[42]

TABLE 3-5. SELECTED MAXIMUM REMOVALS OBTAINED IN THE WET SCRUBBER[39]

Surfactant	Surfactant Conc. (Wt. %)	Organic Inlet Conc. (ppm)	Organic Removal at Outlet (%)
	- Acetone -		
Aerosol 22	1.0	14.4	99
	1.0	23.7	99
Arosurf GMS-E20	0.5	17.5	96
Atlas G-2127	1.0	17.2	99
Product BCO	0.1	38.0	99
Tex-Wet 1001	0.1	-	99
Varifoam YM	0.2	14.4	99
Varsulf H-88	1.0	16.7	99
	- Benzene -		
Aerosol 22	1.0	8.2	94
Arosurf GMS	1.0	16.5	22
Atlas G-2127	1.0	12.1	97
Product BCO	0.5	7.7	98
Tex-Wet 1001	0.1	12.0	97
Varifoam YM	0.2	8.2	94
Varsulf H-88	1.0	10.5	82
	- Carbontetrachloride -		
Aerosol 22	1.0	12.6	94
Arosurf GMS-E20	0.2	8.5	32
	1.0	10.0	42
Atlas G-2127	1.0	11.4	98
Product BCO	0.5	11.1	98
Tex-Wet 1001	0.1	17.0	86
	0.5	15.0	73
	1.0	8.0	94
Varifoam YM	0.2	10.0	94
Varsulf H-88	1.0	6.6	93
	- Toluene -		
Aerosol 22	0.5	9.6	43
	1.0	9.5	93
Arosurf GMS-E20	1.0	9.9	18
Atlas G-2127	0.5	8.9	34
	1.0	6.2	95
Product BCO	0.5	10.9	93
Tex-Wet 1001	0.1	-	96
Varifoam YM	0.1	5.2	47
	0.5	4.6	84
Varsulf H-88	0.2	9.9	45
	- p-xylene -		
Aerosol 22	1.0	3.4	74
Arosurf GMS-E20	0.5	5.0	68
Atlas G-2127	1.0	3.8	91
Product BCO	0.1	2.8	90
Tex-Wet 1001	0.1	3.0	81
Varifoam YM	0.2	1.4	96
Varsulf H-88	1.0	1.8	89

OFFSET LITHOGRAPHY PRINTING

In lithography the printing and nonprinting surfaces are on the same plane. The image area is made of material that can only be wet by ink and the non-image area is made of material that can only be wet by water. The plates are first wet with water containing 0 to 30% isopropanol, then with ink.[37] Most lithographic operations are web-offset and plants classified under commercial lithography mainly operate with sheet-fed lithographic equipment. Although capture problems are significant, no data was available on new capture procedures.

Inks used for web-offset lithography must dry within one second to avoid smudging. "Heat-set" inks developed for this application contain 35 to 45% hydrocarbons and are dried at 400-500°F.[37] Most methods of reducing hydrocarbon emissions from offset printing are the same as for rotogravure printing.

A Japanese patent illustrates a way emissions from drying ovens can be controlled by a waste gas treatment process consisting of a heater and a catalyst; the waste gas is heated and then catalytically oxidized. A part of the treated gas from the catalytic oxidation step is diverted and recycled into the exit side of the demister. When the system is not in operation, a heated inert gas is passed through the system. The above procedures prevent a mist formation in the catalytic bed, thereby improving the catalyst life.[43]

A fluid bed carbon adsorber could be used for this process. An explanation with cost is given in the rotogravure section.

The Reeco Co., Inc. in Morris Plains, N.J. manufactures a high thermal energy recovery technique which incorporates hydrocarbon control.[44] Their

RE-Therm Unit can be utilized on almost any solvent stream. A further explanation of this system with costs is in the rotogravure section discussed as pebble bed incineration.

Modified wet scrubbing of organic vapors using surfactants would be potentially applicable for this process. An explanation of this system is in the rotogravure section.

SOLVENT COATING/ADHESIVE LITHOGRAPH PRINTING

A significant source of organic emissions occurs in the application of adhesive coatings and arises during the drying process. Although capture problems are significant, no data was available on new capture procedures. An arrangement of air pollution control equipment comprised of an "Aerosol Precipitator" and carbon adsorber was designed to allow for maximum submicron particulate and condensible and non-condensible hydrocarbon removal from a solvent coating / adhesive lithograph printing operation. Tests have shown an overall system efficiency of 92% hydrocarbon removal. This system's trademark is "Aerosol Precipitator" and is sold by the Aerosols Control Corporation of Montvale, New Jersey.[45]

A fluid bed carbon adsorber could be used for this process. An explanation with cost is given in the rotogravure section.

Modified wet scrubbing of organic vapors using surfactants potentially holds a good outlook for scrubbing low concentrations of solvent vapors. Removal efficiencies of up to 99% have been observed.[39] More details of this system are explained under the rotogravure printing section.

SURFACE COATING OF CANS

Solventless coating systems are being looked at more and more by the can industry due to environmental regulations and higher energy costs.

This push has resulted in Standard T Chemical Company's developing what appears to be a solution for electro-coating in the can industry.

Standard T has developed and is continuing to perfect an electrocoat system termed "Microdep," so named because it reduces the time needed for electrodeposition from 60 to 120 seconds to approximately 0.5 second or less. The new process seems to be ideal for can manufacturers and a pilot plant employing "Microdep" is currently being built.[46]

According to Lold R. Borwer, Director of Development for Standard T's Chemical Coating Division: "While there is currently no commercial system around, a prototype system is due to be completed within thirty days. It will have the capacity to coat 300 cans per minute, using the "Microdep" system. And faster systems are in the works. A process that could coat 900 to 1,000 cans per minute is not far off."[46]

There are problems with applying "Microdep" technology to the food processing industry. The problem is finding suitable polymers which can be electro-coated, are acceptable to the FDA, and will withstand rigorous requirements of the food packing industry.[46]

NON-VOLATILE STRIPPING OF COATINGS

There are coatings which are nonsusceptable to solvent removal. The Research Systems Development Area of Wright Patterson Air Force Base is looking for nonsolvent techniques of removing paints without using aggressive chemicals. Sandblasting has two disadvantages. It causes particulate emissions and an accumulation of sand in or near areas where the Air Force would prefer not to have sand. A system is now being investigated which uses cold carbon dioxide (CO_2) pellet blasting. Carbon dioxide is pelletized with refrigeration, then used in lieu of sand in a blasting system to

remove the coating and then vaporizes harmlessly into the atmosphere. This program started around the first of September 1978.[47]

PAINTING BOOTHS AND OVENS

Painting of furniture, automotive parts and other large surfaces usually requires the use of a paint booth to apply the coating and an oven for curing. The booth, flash-off area, and the oven constitute the three major emission sources from standard booth painting. The following are hydrocarbon control systems used by various manufacturers utilizing booths and results of a patent search.

1. Union Carbide has started marketing a fluid bed carbon adsorber called Pura Siv based on Japanese technology. This system is explained under the rotogravure printing section.

2. For over two years, Ford Motor Company has tested a noble-metal-impregnated activated charcoal catalyst as a potential low temperature catalyst for the control of hydrocarbon emissions. Preliminary pilot studies have shown that this catalyst is efficient for the control of odor and hydrocarbon emissions from an enamel small parts paint-bake oven operating at 475°F. Hydrocarbon and odor reduction efficiencies remained constant over a period of 160 hours of assembly line operation, averaging 90% and 92%.[48]

The use of this catalyst for other types of paint emissions needs to be examined. It is anticipated that problems may be incurred when these catalysts are used for the control of emissions generated from the baking of car bodies or from the use of paints containing amines.[48]

3. A Japanese patent illustrates a way of removing paint and solvent and paint mist from a painting booth waste gas. This system consists of a

separator, a deodorizer and an afterburner. The separator contains rotating plates, rotating brushes and sprayers. The deodorizer contains an activated carbon deodorizing medium, medium deflectors, a steam pulse maker to prevent sticking of the medium on pipe and walls, and an activated carbon regenerator. The desorbed gas from the carbon is burned in the afterburner.[49]

4. A German patent describes a process whereby waste gases containing organic compounds, particularly off gases from coating installations, are purified by scrubbing with high boiling organic solvents. A 500 m^3/h lacquering installation off gas is scrubbed with spindle oil in a packed tower with 6 seconds contact time, cooling the gas. During 16 days operation the carbon content of the off gas was $\leq$ 400 mg/m^3.[50]

5. A Japanese patent describes a process whereby waste gases containing pollutants are scrubbed with a 1-50% activated carbon slurry. A waste gas containing 1200 ppm methanol and 80 ppm ethylene dichloride was passed through a 6% aqueous activated carbon slurry resulting in a flue gas of 30 ppm methanol and 8 ppm ethylene dichloride.[51]

6. A modified wet scrubbing technique using surfactants could potentially be used in this application. This system is explained under the rotogravure printing section.

ARCHITECTURAL SURFACE COATINGS

Architectural surface coatings (ASC) are stock type or shelf goods formulated for normal environmental conditions and general applications on new and existing residential, commercial, institutional, and industrial structures. ASC are not applied as part of a manufacturing process nor are they generally formulated for exposure to:

- extreme temperatures
- chemicals
- fumes
- etc.

ASC are applied in situ to the general range of architectural structural or surface finishing materials.[52]

All ASC use either solvents* or water as the carrier for the resins, pigments, and additives in the coatings. Certain solvents, primarily glycols, are added to water-borne coatings to aid in emulsification, in coalescence or film formation, to impart freeze-thaw resistance, or to promote certain other properties of these coatings. When compared to the amount of solvents in solvent-borne ASC, the amount of solvents in water-borne ASC is relatively minor. For 1975 the solvent in water-borne ASC to solvent in solvent-borne ASC ratio was approximately 1:5.[53]

Volatile organic compounds (VOC) are given off by all ASC upon air drying. Such surface air drying is the predominant source of VOC emissions from ASC. VOC emissions from thinning and cleanup solvents, used in conjunction with ASC, constitute the remainder of such emissions making up a little over 20 percent of the total emissions attributable to the use of ASC.[52]

Since most emissions result from air drying of the coatings on surfaces, only one method exists to reduce VOC emissions: that is to reduce or eliminate the solvent used in the formulation of these coatings. This can be done by either of the below options:

- Developing water-borne ASC to replace solvent-borne coatings in certain applications.

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*Solvents here mean organic solvents.

- Lowering the solvent content of solvent-borne ASC. This can sometimes be accomplished by going to higher solids formulations but is often infeasible because of unacceptable changes in other system properties, such as viscosity.[52]

Other advanced technologies are being investigated, but, as yet, are still in their infancies and have contributed little to the ASC industry.

Water-borne coatings are able to replace solvent-borne coatings under certain circumstances in the following applications:[52]

- Exterior
  - Wall paints (nongloss and gloss)
  - Enamels
    * Porch, deck, and floor
    * Sash, trim, and trellis
  - Barn and fence paints
  - Stains (except for extractive bleeding woods)
- Interior
  - Nongloss wall paints
  - Enamels (glosses and semiglosses)
  - Stains (except for extractive bleeding woods)
- Miscellaneous
  - Roof coatings
    * Asphaltic emulsions
    * Aluminum pigment emulsions

Circumstances under which water-borne ASC cannot be used are primarily of climatological consideration (i.e., high and low temperatures and humidities).[52]

It is expected that, in certain cases, where lower-performance water-borne coatings are used in lieu of superior solvent-borne coatings, substrate protection may suffer. This can be minimized through diligence on the part of the customer in understanding the requirements of the surface to be coated and the properties of the coating to be applied.[52] Some draw-backs in the use of water-borne ASC include: difficulty of application on certain surfaces (e.g., chalk, masonry, and greasy surfaces), lower quality for certain properties in certain applications compared to solvent-borne ASC (e.g., glossiness, durability, etc.), etc.[53]

Higher solids formulations are being investigated by many coatings manufacturers and all major resin suppliers to the ASC industry. Research on higher solids coatings in the industrial finishing industry, of which the ASC industry is part, has resulted in coatings of 65-70% volume solids. It is expected that within five years such coatings may approach 80-90% volume solids. Such coatings have been developed in the ASC industry for limited uses and experimentation.[54] It should, however, be noted that these higher solids coatings are almost exclusively special purpose ASC and their ultimate use would constitute a relatively minor portion of total ASC use (<10%).

An emerging advanced technology that has recently been investigated and has proven successful in certain uses is airless electrostatic ASC application. It is based on charging the coating and grounding the surface during application.[55] When the positively charged coating is sprayed on the grounded surface, the coating particles are attached to the surface due to the electric field strength. Such a technique offers the following advantages in certain instances over conventional ASC:

- Lower solvent use per application
- Less overspray than conventional spraying
- More uniform coating thickness
- Uses on steel and aluminum
- Probable manpower savings
- Possible cost reduction

This technology might well be used for metal buildings, bridges, storage tanks, pipelines, towers, etc. Ultimate use of this advanced technology is expected to amount to a relatively low percent of total ASC use. In many instances advanced technologies, such as airless electrostatic ASC application, would compete for the same end uses as higher solids coatings.

SUMMARY

Data on abatement method, range of control, application limits/benefits, cost and availability are summarized in Table 3-6.

TABLE 3-6. STATIONARY SOURCE HYDROCARBON CONTROL TECHNIQUES

PROCESS DESCRIPTION/SCC	ABATEMENT METHOD	RANGE OF CONTROL	APPLICATION LIMITS/BENEFITS	COST	AVAILABILITY	DATA REF.
Ethylene/ 30159999	Emergency Flare Emissions	Backup Compressor or Flare	320 tons/yr reduction during the first four years of 10^6 lb plant	Steam limitations for flare	$14 M estimated mid-1979 capital. Plant savings could reduce this cost	Available Now	9
	Catalyst Regeneration	SOP for catalyst regeneration should become a two-step process	≈70-90%		Small additional cost of quench tower operating a few days longer and more TOC analysis on steam condensate	Available Now	
	Change Gas Compression Seal Oil Degassing Area	Discharge Piped to Existing Flare	up to 99% in flare	Wind conditions can affect collection efficiency at degassing area	Ductwork around degassing area and piping to nearest flare line	Available Now	
	Sampling Stations	Closed Sampling Loop	99+%		$100 to $3,000/sampling station	Available Now	23
	Transfer and Injection Pumps	Seal-Less Pumps	100%	Not considered Booster Pumps. Size limitation	See Table 1	Available Now	26
	Transfer and Injection Pumps	Magnetic Pumps	100%	Not considered Booster Pumps. Size limitation	See Table 1	Available Now	28, 29
	Metering and Proportioning Pumps	Diaphragm Pumps	100%	Hp Increases rapidly with > 200 centipose Fluids.	20 - 25% Higher See Table 1	Available Now	29
	Manual 6" or Less Ball Valves	Sealed Ball Valve Manual 6" or Less	100%	Space Requirements on Retrofit	40 - 50% more than unsealed valve	Available Now	19, 20, .
	Manual 6" or Greater Ball Valves	Sealed Ball Valve Manual Greater 6"	100%	Space Requirements on Retrofit	40 - 50% more than unsealed valve	≈ 1980	19, 20, .
	Actuated Ball Valves	Sealed Ball Valve Actuated	100%	Space Requirements on Retrofit		≈ 1980 - 1981	12, 20, .
	Small HC Streams	Catalyst (500° - 600°F) with Elec. Preheater	99%	Metals poison catalyst	$4,500 for a 100 ppm 100 SCFM Input	Available Now	31
	Storage Tanks	Accordian Type Tank Liner	0.04 to 0.05 g/day per ft.^{2} of liner	Liner tested mainly with gasoline, may not be suitable for some liquids	Cost of floating roof plus $30,000 for a 40 ft. ht. x 100 ft.d. tank	≈ 1981	34, 35
	Loading and Unloading	Closed Loading System	up to 95%	Assuming flare or other HC control system is nearby	Approx. $10,000 to $50,000 capital depending on location of loading area	Available Now	
	Loading and Unloading	Quick Connect Couplings with C_1 vent system	up to 95%	Assuming flare or other HC control system is nearby	Approx. $2,000/coupling system capital	Available Now	

TABLE 3-6. STATIONARY SOURCE HYDROCARBON CONTROL TECHNIQUES (CONTINUED)

PROCESS DESCRIPTION/SCC		ABATEMENT METHOD	RANGE OF CONTROL	APPLICATION LIMITS/BENEFITS	COST	AVAILABILITY	DATA REF.
Acetaldehyde/ 30199999	Sampling Stations	Closed Sampling Loop	99+%		$100 to $3,000/sampling station	Available Now	23
	Transfer and Injection Pumps	Seal-Less Pumps	100%	Not considered Booster Pumps. Size limitation	See Table 1	Available Now	26
	Transfer and Injection Pumps	Magnetic Pumps	100%	Not considered Booster Pumps. Size limitation	See Table 1	Available Now	28, 29
	Metering and Proportioning Pumps	Diaphragm Pumps	100%	Hp Increases rapidly with > 200 centipoise fluids	20 - 25% Higher See Table 1	Available Now	29
	Manual 6" or Less Ball Valves	Sealed Ball Valve Manual 6" or Less	100%	Space Requirements on Retrofit	40 - 50% more than unsealed valve	Available Now	19, 20,
	Manual 6" or Greater Ball Valves	Sealed Ball Valve Manual Greater 6"	100%	Space Requirements on Retrofit	40 - 50% more than unsealed valve	≈ 1980	19, 20,
	Actuated Ball Valves	Sealed Ball Valve Actuated	100%	Space Requirements on Retrofit		≈ 1980 - 1981	19, 20,
	Small HC Streams	Catalyst (500° - 600°F) with Elec. Preheater	99%	Metals poison catalyst	$4,500 for a 100 ppm 100 SCFM Input	Available Now	31
	Storage Tanks	Accordian Type Tank Liner	0.04 to 0.05 g/day per ft.^{2} of liner	Liner tested mainly with gasoline, may not be suitable for some liquids	Cost of floating roof plus $30,000 for a 40 ft. ht x 100 ft.d. tank	≈ 1981	34, 35
	Loading and Unloading	Closed Loading System	up to 95%	Assuming flare or other HC control system is nearby	Approx. $10,000 to $50,000 capital depending on location of loading area	Available Now	
	Loading and Unloading	Quick Connect Couplings with C_1 Vent System	up to 95%	Assuming flare or other HC control system is nearby	Approx. $2,000/coupling system capital	Available Now	
Glycerol/ 30199399	Abatement Methods under Acetaldehyde process apply to glycerol						
Polypropylene/ 30101602	Abatement Methods under Acetaldehyde process apply to polypropylene						

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TABLE 3-6. STATIONARY SOURCE HYDROCARBON CONTROL TECHNIQUES (CONTINUED)

PROCESS DESCRIPTION/SCC		ABATEMENT METHOD	RANGE OF CONTROL	APPLICATION LIMITS/BENEFITS	COST	AVAILABILITY	DATA REF.
HDPE/ 30101802	Sampling Stations	Closed Sampling Loop	99+%		$100 to $3,000/sampling station	Available Now	23
	Transfer and Injection Pumps	Seal-Less Pumps	100%	Not considered Booster Pumps. Size limitation	See Table 1	Available Now	26
	Transfer and Injection Pumps	Magnetic Pumps	100%	Not considered Booster Pumps. Size limitation	See Table 1	Available Now	28, 23
	Metering and Proportioning Pumps	Diaphragm Pumps	100%	Hp Increases rapidly with > 200 centipoise fluids	20 - 25% Higher See Table 1	Available Now	29
	Manual 6" or Less Ball Valves	Sealed Ball Valve Manual 6" or Less	100%	Space Requirements on Retrofit	40 - 50% more than unsealed valve	Available Now	19, 20, 2
	Manual 6" or Greater Ball Valves	Sealed Ball Valve Manual Greater 6"	100%	Space Requirements on Retrofit	40 - 50% more than unsealed valve	≈ 1980	19, 20, 2
	Actuated Ball Valves	Sealed Ball Valve Actuated	100%	Space Requirements on Retrofit		≈ 1980 - 1981	19, 20, 2
	Small HC Streams	Catalyst (500° - 600°F) with Elec. Preheater	99%	Metals poison catalyst	$4,500 for a 100 ppm 100 SCFM Input	Available Now	31
	Storage Tanks	Accordian Type Tank Liner	0.04 to 0.05 g/day per ft.^{2} of liner	Liner tested mainly with gasoline, may not be suitable for some liquids	Cost of floating roof plus $30,000 for a 40 ft. ht x 100 ft.d. tank	≈ 1981	34, 35
	Loading and Unloading	Closed Loading System	up to 95%	Assuming flare or other HC control system is nearby	Approx. $10,000 to $50,000 capital depending on location of loading area	Available Now	
	Loading and Unloading	Quick Connect Couplings with C_1 Vent System	up to 95%	Assuming flare or other HC control system is nearby	Approx. $2,000/coupling system capital	Available Now	11, 12,
LDPE/ 30101a02		New Union Carbide LDPE Process	2 lb/ton of product	Licensing must be obtained from Union Carbide. Plant specifications are different, therefore, mainly applicable to new plants. Overall new plant controls allow products to be manufactured at competitive prices. No additional cost data was available for this study.		Available Now	11, 12,

All abatement methods under HDPE process apply to LDPE also

TABLE 3-6. STATIONARY SOURCE HYDROCARBON CONTROL TECHNIQUES (CONTINUED)

PROCESS DESCRIPTION/SCC	ABATEMENT METHOD	RANGE OF CONTROL	APPLICATION LIMITS/BENEFITS	COST	AVAILABILITY	DATA REF.
Petroleum: Compressor seal/30600804	Hood Compressor Seal Area and Pipe to Nearest Flare Line	up to 99% in flare	Assume double mech. seals or packed glands already in use, wind conditions can affect collection efficiency	Ductwork around area and piping to nearest flare	Available Now	
TCC regenerator/30600301	High Temp. Operation of Newer Designed TCC Regenerators	100%	Existing TCC regenerators often cannot withstand high temp.		Available Now	17, 18
Manual 6" or Less Ball Valves/3060081	Sealed Ball Valve Manual 6" or Less	100%	Space Requirements on Retrofit	40 - 50% more than unsealed valve	Available Now	19, 20, 2
Manual 6" or Greater Ball Valves/30600801	Sealed Ball Valve Manual Greater 6"	100%	Space Requirements on Retrofit	40 - 50% more than unsealed	= 1980	19, 20, 2
Actuated BAll Valves/30600801	Sealed Ball Valve Actuated	100%	Space Requirements on Retrofit		= 1980 - 1981	19, 20, 2
Transfer and Injection Pumps/30600803	Seal-Less Pumps	100%	Not considered a Booster pump. Size limitations	See Table 1	Available Now	26
Transfer and Injection Pumps/30600803	Magnetic Pumps	100%	Not considered a Booster pump. Size limitations	See Table 1	Available Now	28, 29
Metering and Proportioning Pumps/30600803	Diaphragm Pumps	100%	Hp increase rapidly with > 200 centipoise fluids	20 - 20% higher See Table 1	Available Now	29

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TABLE 3-6. STATIONARY SOURCE HYDROCARBON CONTROL TECHNIQUES (CONTINUED)

PROCESS DESCRIPTION/SCC	ABATEMENT METHOD	RANGE OF CONTROL	APPLICATION LIMITS/BENEFITS	COST	AVAILABILITY	DATA REF.
Petroleum Storage: Fixed Roof (Crude Oil)/ 40300102 & 40300104	Accordian Type Tank Liner	0.04 to 0.05 g/day per ft.^{2} of liner	Liner tested mainly with gasoline, may not be suitable for some liquids. TK does not have to be "round" for retrofitting	Cost of floating roof plus $30,000 for a 40 ft. ht. x 100 ft.d. TK. Cost extrapolation beyond this size is estimated to be proportional to the tank diameter.	≈ 1980 - 1981 testing in progress	34, 35
Fixed Roof (Distillate Oil)/ 40300107 & 40300152	Accordian Type Tank Liner	Same as above	Same as above	Same as above	Same as above	34, 35
Fixed Roof (Gasoline)/ 40300101 & 40300103	Accordian Type Tank Liner	Same as above	Same as above	Same as above	Same as above	34, 35
Floating Roof (Crude Oil)/ 40300203	Accordian Type Tank	Same as above	Same as above	$30,000 for a 40 ft. ht. x 100 ft.d. TK	Same as above	34, 35
Floating Roof (Gasoline)/ 40300202	Accordian Type Tank Liner	Same as above	Same as above	Same as above	Same as above	34, 35

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TABLE 3-6. STATIONARY SOURCE HYDROCARBON CONTROL TECHNIQUES (CONTINUED)

PROCESS DESCRIPTION/SCC	ABATEMENT METHOD	RANGE OF CONTROL	APPLICATION LIMITS/BENEFITS	COST	AVAILABILITY	DATA REF.
Gravure:						
Dryers and Solvent/40500501	Carbon adsorption	90% removal in adsorber	Limited by capture efficincy from printing units and dryers. Adsorption used mainly for publication gravures	See Table 3	Available Now	38
Dryers and Solvent/40500501	Pebble Bed Incinerator	90% removal in incinerator	Limited by capture efficiency from printing units and dryers. Pebbel bed used for publication and packaging gravures	See Table 2	Available Now	38
Dryers and Solvent/40500501	Thermal Incinerator	90% removal in incinerator	Limited by capture efficiency from printing units and dryers. Incineration used mainly for packaging gravures.	See Figures 4 & 5	Available Now	38
Dryers and Solvent/40500501	Wet Scrubbing	up to 99%	Only bench scale testing has been made at this time	No Cost Available	Bench scale testing at this time	39
Dryers and Solvent/40500401	Pura Sir-HR	90% in 140,000 SCFM Stream 10 ppm in with 1 ppm out	Limited by capture efficiency from printing units and dryers.	≈$100/SCFM low flow, hi conc. ≈$5/SCFM hi flow, low conc.	Available Now	41
Dryers and Solvent/40500501	Automated Catalytic Incineration	95% or greater	same as above			42
Lithography:						
Adhesive/40500401	"Aerosol Precipitator"	92%	Same as above		Available Now	45
Dryers and Solvent/40500401	Wet Scrubbing	up to 99%	Only bench scale testing has been made at this time	No Cost Available	Bench scale testing at this time	39

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TABLE 3-6. STATIONARY SOURCE HYDROCARBON CONTROL TECHNIQUES (CONCLUDED)

PROCESS DESCRIPTION/SCC	ABATEMENT METHOD	RANGE OF CONTROL	APPLICATION LIMITS/BENEFITS	COST	AVAILABILITY	DATA REF.
Pesticides/30103399 and highly toxic chemicals, such as PCB, PNA, Kepone etc.	Microwave-induced oxygen plasma	99+%		See pg. 20	10-30 lb/hr system will be tested	36
Can Coating	Electro-coating using "Microdep"	No control efficiencies given	Finding polymers acceptable for food packing	Competitive with other coating systems. No additional cost information was available.	Pilot Plant being built now	46
Enamel Auto Parts Paint-Bake Oven	Impregnated Activated Charcoal Catalyst	90-92%	Problems may occur if used for car body baking or paints containing amines		Tested at For Motor Co. for two years	48

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